

UNIVERSITY OF CANTERBURY

HUMAN INTERFACE TECHNOLOGY LABORATORY
NEW ZEALAND

A Study on the Usability of Hand-Held and Wearable Head-Mounted Displays in Clinical Ward Rounds

Author: Muhammad Nda YAKUBU

Supervisor: Professor Mark BILLINGHURST

Co-Supervisor: Dr. Agnieszka SZOSTEK

Co-Supervisor: Dr. Gun LEE

Co-Supervisor: Dr. Pleayo TOVARANONTE

Dissertation submitted in partial fulfilment for the degree of
Master of Human Interface Technology at the
Human Interface Technology Laboratory New Zealand,
College of Engineering,
University of Canterbury
March 23, 2015

Abstract

In this thesis research, we investigate the usability of hand-held display (Tablet PC) and wearable head-mounted display (Google Glass) interfaces and their effect on doctor-patient interaction during clinical ward round in the hospital. We looked at existing literature to identify existing research about our topic. Using a user centered Interaction Design process we developed a prototype hybrid system that used both a hand-held and head mounted display. An evaluation of this prototype with a hand-held system and a paper based interface was performed in a simulated patient room with 20 doctors and 5 patients. The participants were observed, surveyed, and interviewed about their experiences. Generally, the patients had a high satisfaction rate and felt the interfaces were not causing the doctors to lose focus on them. The doctors found the hand-held display by itself and existing paper-based interface to be the most usable and least distracting interfaces for accessing patient information during clinical ward rounds.

Declaration

I, Muhammad Nda Yakubu, declare that this thesis titled, 'A Study on the Usability of Hand-Held and Wearable Head-Mounted Displays in Clinical Ward Rounds.' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.

Acknowledgements

The author would like to sincerely thank Professor Mark Billingham, Dr. Agnieszka Szostek for their guidance, inspiration, encouragement and supervision, Dr. Gun Lee for all his help and valuable feedback with analysing the study data. Many thanks go out to Jan Behrens for his support, inspiration and encouragement to pursue this degree. I will like to extend my sincere thanks to Dr. Pleayo Tovarante for helping out with all the clinical ward rounds, focus groups, interviews, his guidance and wisdom. I will also like to extend my sincere appreciation to Orion Health for giving me the opportunity to do this research, all Orion Health Christchurch office, especially Team Planet Express for their valuable feedback and support. Victoria for her encouragement, push, support and keeping me motivated and also my family for all their support, advices and encouragement. In addition, the author would also like to thank all students and staff of Human Interface Technology New Zealand for all the support and inspiration, as well as creating a comfortable and friendly research environment.

Contents

Abstract	i
Declaration	ii
Acknowledgements	iii
Terminology	ix
Abbreviations	x
1 Introduction	1
1.1 Problem Domain	2
1.2 Research Purpose and Rationale	3
1.3 Mobile Technologies in Healthcare	4
1.3.1 Hand Held Displays	4
1.3.2 Head Mounted Displays	4
1.4 Research Focus	6
1.5 Research Approach	7
1.5.1 Prototype	7
1.5.2 The Use of Interaction Design Process	7
1.6 Thesis Summary	9
2 Related Work	10
2.1 Electronic Health Record in Doctor-Patient Interaction	10
2.2 Use of Hand Held Display Computers in Healthcare	11
2.3 Use of Wearable Computers in Clinical Ward Round	13
2.4 Social Acceptance of Wearable Technologies	16

2.5	Hybrid Display Systems: A Combination of Head Mounted and other Secondary Displays	19
2.6	Use of Google Glass™ in Healthcare	21
2.7	Doctor's Behaviour during Consultation	23
2.8	Limitations of Existing Research and Research Opportunities	24
3	Needs Analysis	25
3.1	Observational Study	25
3.1.1	Stakeholders:	26
3.1.2	Current Workflow of the Clinical Ward Round:	27
3.1.3	Clinicians Interviews	32
3.1.4	Focus Groups	33
3.2	Findings	33
3.2.1	Observation Feedback	33
3.2.2	Interview and Focus Group Feedback	35
3.3	Requirements	40
4	Design	42
4.1	User Centred Design of Solution	42
4.2	Low Fidelity Prototype Iteration	45
4.3	High Fidelity Prototype	51
4.4	How Design met Requirements	55
5	Implementation	57
5.1	Final Prototype Implementation	57
5.2	Implementation Details	62
5.2.1	System Architecture	62
5.3	Hardware	65
5.3.1	Hand Held Display	65
5.3.2	Head Mounted Display	65
6	User Evaluation	67
6.1	Research Questions	67
6.2	Evaluation Goals	68
6.3	Experiment Setup	68
6.4	Experiment Design	70
6.5	Experiment Scenarios	71
6.6	Measurements	72

6.7	Participants	75
6.8	Experimental Procedure	76
6.9	Pilot Testing	77
7	Results and Discussion	78
7.1	Statistical Results	78
7.1.1	Usability	80
7.1.2	Doctor-Patient Interaction (Doctor Perspective)	82
7.1.3	Doctor-Patient Interaction (Patient Perspective)	86
7.2	Qualitative Feedback	87
7.2.1	Discussion	91
7.3	Threats to Validity	95
7.4	Unanswered Questions	96
7.5	Results Summary	96
8	Conclusion and Future Work	98
8.1	Conclusion	98
8.2	Contribution	98
8.3	Future Research	99
A	Hardware Specifications	109
B	Information Sheet and Consent Form	111
C	High Fidelity Prototype	116
D	Final Prototype	123
E	Experiment Advertisement	129
F	Patients Clinical Note Folders	132
G	Patient Scripts	139

List of Figures

1.1	Head Mounted Display	5
1.2	User Centered Interaction Design Process, sourced from [66]	8
2.1	Different types of wearable technology gadgets, sourced from [55]	14
2.2	Q-Belt Integrated Computer, sourced from [43]	15
2.3	QBIC Scenario, sourced from [1]	15
2.4	Prototype campus information system, sourced from [19]	20
2.5	An anaesthesiologist intubates a mannequin while monitoring vital signs using a head-mounted display, sourced from [41]	21
3.1	Clinical Ward Round Workflow	28
3.2	Patient Status Communication Board	29
3.3	Clinicians Retrieving Clinical Note from Trolley	30
3.4	Unused Computer on Wheel Laptops	34
4.1	Head Mounted and Hand Held Displays	43
4.2	A ward round session using hand held and head mounted display interfaces	44
4.3	Main menu of the Prototype Application on Tablet PC	46
4.4	Clinical Notes page the Prototype Application on Tablet PC	47
4.5	Medication List on the Prototype Application on Tablet PC	48
4.6	Patient Results on the Prototype Application on Tablet PC	48
4.7	Patient CT Scan on the Prototype Application on Tablet PC	49
4.8	Cards on the Prototype Application on Google Glass™	50
4.9	Main menu on the Tablet PC for High fidelity prototype	52
4.10	Patient list view on the Tablet PC for High fidelity prototype	52
4.11	Patient Demographics on High Fidelity prototype	53

4.12 Patient Allergy High Fidelity Prototypes	54
5.1 Application Landing Page	58
5.2 Patient Referral view on Tablet PC	60
5.3 Patient Referral view on Google Glass™	61
5.4 Note and Result views on Tablet PC	62
5.5 System architecture of the HybridEHR	63
5.6 Google Glass™	66
6.1 Patient Bedside	69
6.2 Participants answering Questionnaires on Computers	70
7.1 Junior Doctors Usability Score of the three different Interfaces	81
7.2 Senior Doctors Usability Score of the three different Interfaces	82
7.3 Junior Doctors ability to complete tasks across the three In- terfaces	83
7.4 Senior Doctors ability to complete tasks across the three In- terfaces	84
7.5 Vital signs monitoring HMD, sourced from [39]	93
B.1 Information Sheets	112
B.2 Information Sheets	113
B.3 Consent Form	114
B.4 Ethics Approval	115
C.1 Patient Demographic View on Google Glass	122
C.2 Patient Allergy View on Google Glass	122

List of Tables

6.1	Doctor Questionnaire	73
6.2	Patient Satisfaction Questionnaire	73
6.3	Interface Ranking Questionnaire	74
6.4	Interface Preference Questionnaire for Patients	75
7.1	Participant Demographics	79

Abbreviations

HHD - **H**and **H**eld **D**isplay

HMD - **H**ead **M**ounted **D**isplay

GG - **G**oogle **G**lass

CWD - **C**linical **W**ard **R**ound

QR - **Q**uick **R**esponse **C**ode

EHR - **E**lectronic **H**ealth **R**ecord

PDA - **P**ersonal **D**igital **A**ssistant

GP - **G**eneral **P**ractitioner

HHD+HMD - Combined use of **HHD** **H**and **H**eld **D**isplay and **HMD** **H**ead **M**ounted **D**isplay

IQR - **I**nter **Q**uartile **R**ange

Mdn - **M**edian

PC - **P**ersonal **C**omputer

AR - **A**ugmented **R**eality

Chapter 1

Introduction

Hospitals around the world are increasingly adopting Electronic Health Records (EHRs) with the hope that their introduction will improve quality of health care, information exchange and patient satisfaction. Using EHR during Clinical Ward Rounds (CWRs) brings many benefits, such as improved decision-making ability, better adherence to guidelines, access to laboratory and radiology information, reduced medical errors and improved information sharing, it also made it more difficult for clinicians to maintain good doctor-patient interaction. However, with the advent of new hand held and wearable devices, such as tablet PCs and Google GlassTM(GG), electronic health information could be easily accessed in less disruptive, more interactive, and efficient ways.

In most cases, EHRs have helped improve health care by providing better adherence to guidelines, access to laboratory and radiology information, improved decision-making and information sharing and reduce medical errors. Despite all these benefits, EHRs have also been known to make doctor-patient interaction more difficult for most clinicians using them during Clinical Ward Rounds (CWRs). However, with the advent of new handheld and wearable devices, such as tablet PCs and Google GlassTM(GG), electronic health information can be easily accessed in less disruptive, more interactive, and efficient ways.

1.1 Problem Domain

This thesis is focused on investigating how Hand Held Devices (HHD) and wearable Head Mounted Displays (HMD) can be used by clinicians, in order to take advantage of their individual strengths to improve doctor-patient interaction, specifically during CWR in the hospital. These devices could help improve access to patient information, which is crucial for decision making during CWRs.

The CWR is a key clinical process in which doctors and their clinical teams review, plan and provide high quality care to patients. During the CWR, critical decisions about patients are made, such as diagnosis, prescription of medication, analysis of laboratory and radiology results, as well as communication of management plans to patients. The CWR also allows clinicians to build rapport and trust with their patients, while simultaneously treating them. It also empowers all individuals involved in patient care to work together in developing a co-ordinated plan of care. In addition, CWR provides an opportunity for gaining knowledge and sharing of information between members of the clinical team.

In order to be able to make informed decisions for diagnosis and treatment, it is important that clinicians have access to the latest and most complete information about their patients, while still having the ability to maintain a good relationship with them. However, in existing CWR processes, clinicians heavily rely on paper-based documentations as the main source of information at the patient's bedside. The following are some of the problems with the existing systems:

- Excessive time spent on finding information.
- Incomplete view of patient information.
- Unreliable information storage techniques.
- Storage and transportation of bulky clinical notes.
- Privacy breaches/leaking of patient information during clinical ward round.
- Lots of documentation overhead.
- Difficulty in sharing information among healthcare professionals.

- Increased focus time on paperwork rather than on the patient.

All the problems mentioned above heavily contribute to poor doctor-patient interactions, improper diagnosis or decisions, privacy breaches and inefficiencies during the CWR process.

Hence, it is crucial to provide clinicians with vital information at the point of care without compromising doctor-patient interactions. For example, doctors at Boston Hospital are experimenting by using GG, an HMD, and Quick Response (QR) codes to identify patients. Their system allows doctors to scan a patient's code and view patient's health record using GG [69].

The remainder of this document describes our approach to investigate how the problems mentioned above could be solved, using either a wearable HMD, a HHD tablet computers or a combination of both devices during CWRs.

1.2 Research Purpose and Rationale

The research in this thesis is an investigation of how to provide better tools to support clinicians in the CWR process in hospitals. The objective is to assist clinicians, with easy to use state-of-the-art-tools that enhance doctor-patient interaction, support clinician decision making ability and improve patient satisfaction. The main rationale of this research is to provide a better way for clinicians to access health information without the need to look away from the patient. This will improve doctor-patient interaction, as well as enable the clinicians to collaborate with each other in a more positive way. In addition, the clinician leading a CWR will be free to use his hands for patient examination and still have access to the most up-to-date patient information using a HMD or through the supporting clinicians using a HHD. The author believes, that this could lead to an improved doctor-patient interaction, better decision making, and a more efficient and effective CWR process.

1.3 Mobile Technologies in Healthcare

1.3.1 Hand Held Displays

Hand held display devices have been increasingly growing in popularity and adoption during the past few years. Portability, lower power consumption, faster processing ability and stronger capability, cost, and longer battery life are some of the reasons for their high adoption. Some of the most widely used HHD devices are tablet PCs, smart phones and personal digital assistants (PDA)s.

While the overall adoption of HHD devices has been increasing, their adoption in healthcare sector has been relatively low. The healthcare sector has a long history of being slow in the adoption of new technologies in comparison with other industries [24, 38]. A study by Holzinger et al. [25] and Brekka et al. [8], found that clinicians are reluctant to use systems that were not well designed on HHDs, as they are time constrained and their main job is to look after the patient, having a system that distract them from their job can extremely slow them down.

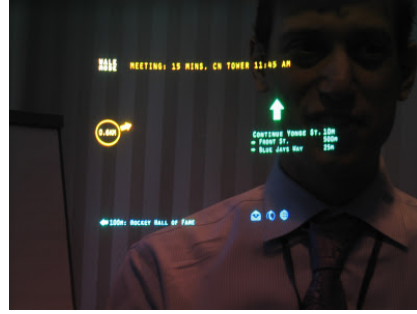
Usability and satisfaction of the systems designed to be used on the HHD interface is certainly one of the main reasons for their slow adoption by the clinicians and the healthcare sector. This is an area that has not been comprehensively researched [53]. A recent study by Criswell et al. [16], revealed that HHDs are mostly used by clinicians as reference devices rather than interfaces for accessing EHR.

1.3.2 Head Mounted Displays

HMDs are devices worn on the head that superimpose computer-generated imagery over a wearer's field of view [40] (Figure 1.1). HMDs are particularly promising for healthcare because they could be used to provide access to vital medical information, such as previous medical history, family history, social history, list of allergies, and vital observations. This is all without the need for the clinician leading a CWR to use his hands to operate a computer or look away from his patient. It also gives him the ability easily to assess a patient.



(a) The Microvision Nomad ND2000 HMD, sourced from [54]



(b) View through the HMD, sourced from [45]

Figure 1.1: Head Mounted Display

Previous research has demonstrated how effective HMDs are at helping clinicians detect critical patient events [40, 39] and their benefit in surgical training [28]. However, viewing certain types of information such as PDF documents or MRI scans, or updating a patient record reliably is impractical and can be difficult using HMDs. The possible inability to access information in these documents could be the difference between life and death in critical situations.

Some of the other shortcomings of HMDs are the limited size of their display [18] and limited ways of interacting with them. Showing too much information on them can cause attentional blindness [63, 31]. As a result, some types of information are more suited for HHD devices such as tablets, which also provide mobility, better input methods and larger screens.

Although, the use of HMDs and HHDs has been previously studied individually in healthcare, there has not been much research work done on the combine use of both interfaces during the CWR process. Some of the previous studies that looked at the use of both devices in non CWR scenarios were Weller et al. [70], Feiner et al. [19], Benko et al. [4], Leupold et al. [35], and Budhiraja et al. [10].

To better understand how the usability of these devices and their adoption can be improved in CWR, this research will distinguish itself from previous

studies by:

1. Exploring the use of a combination of wearable HMD computer and a HHD in clinical ward round.
2. Exploring novel ways of distributing information between HHDs and HMDs.
3. Investigate how usability of the HHDs and HMDs interfaces can be improved during CWR.
4. Studying the effects of using different methods (paper, HHD, and a combination of HHD and HMD) for accessing patient information during doctor-patient interaction in clinical ward round.

1.4 Research Focus

This research focuses on two main things: the doctor-patient interaction and the usability of different systems. Doctor-patient interaction is the way in which a doctor and his patient interact during consultation. Usability is the ease of use and the learn-ability of a system. One of the most obvious solutions that come to mind to the problems stated earlier is to use a tablet PC for accessing relevant information at the patient's bedside, so as to avoid the need for traversing through a compilation of papers. While this approach could work well, it raises the question of how the clinician leading the CWR examine and interact with their patient while looking up information or holding the tablet in a non obtrusive manner.

The traditional paper-based method will be used as a baseline for this research. The research will also entail the use of HHD and HMD as alternative methods of accessing information. It will also compare the differences between using different combinations of these technologies. By comparing them, the most suitable method can be decided upon and systems can be designed that allow clinicians to focus on what they are good at, which is taking care of the patient, while having simultaneous access to all the relevant information they need.

In conducting this research, it is important to make sure that the technology developed does not interfere with existing work practices, and that the

doctor-patient interaction is not affected in a negative way. In order to achieve this, the author will use interaction design methods to understand the problem domain before carrying out trials. This design methodology will serve as a road map for the research and the design process for developing an effective prototype.

1.5 Research Approach

This section describes how interaction design methods were used to facilitate the development of possible solutions.

1.5.1 Prototype

In order to address the research questions outlined above, a prototype system EHR was developed for both a HHD and a HMD. An interaction design process was followed to develop the system as described in the next section.

1.5.2 The Use of Interaction Design Process

User centred Interaction Design is the process of designing an interactive digital product. It is an iterative process that involves identifying user needs by planning, carrying out research of how user works, what their work environment is like, challenges they are facing. It involves creating requirements based on those needs, developing alternative designs that meet those requirements, building interactive alternatives of the designs so they can be communicated and assessed/measured. It also requires continuous evaluation and adapting the design throughout the process, in order to ensure user the requirements are being met [30]. Figure 1.2 shows a visual representation of the user centered interaction design process described above.

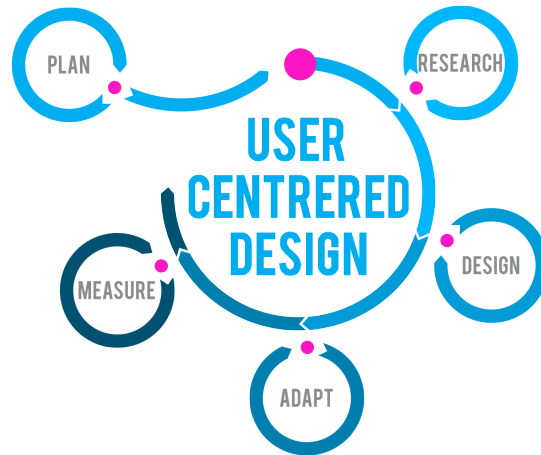


Figure 1.2: User Centered Interaction Design Process, sourced from [66]

Interaction design was chosen as the preferred method, because it focuses on the need of users rather than technical needs. It guides designers towards understanding who the target users are, what environment they work in, their existing processes, the existing challenges they face and how an interactive product can help address those challenges.

1.6 Thesis Summary

This thesis is presented in the following manner:

Chapter 1: Introduction.

Introduces the existing problems in the paper-based clinical ward round process, provides a rationale for introducing new technologies that will contribute towards an improved doctor-patient interaction, patient satisfaction, improved efficiency and decision making, and explains the research focus.

Chapter 2: Background Research.

Provides a review of the relevant literature, identifying existing applications that use hybrid display systems, hand held displays in healthcare, social acceptance of wearables, wearable computers in clinical ward rounds, doctors behaviour during consultation, and use of google glass in healthcare. Reviews the impact that using electronic electronic health records has on doctor-patient interaction during clinical ward rounds.

Chapter 3: Design Process.

Discusses the interaction design process, ward round process and recognises the relevant stakeholders in a ward round.

Chapter 4: Design.

Describes the design process followed for the prototype system.

Chapter 5: Implementation.

Describes the implementation/development process followed for the prototype system.

Chapter 6: Evaluation.

Presents the experimental design for the evaluation of the prototype.

Chapter 7: Results and Discussion.

Presents the statistical results, qualitative feedback of the prototype experiment and discusses the implications of the research.

Chapter 8: Conclusion.

Provides a conclusion of the current research and presents further research for future investigation of hand held display and head mounted display systems in clinical ward rounds.

Chapter 2

Related Work

Due to the number of diverse topics in this study, the research areas have been categorised into different sections. Our research is based on promoting appropriate doctor-patient interactions in Clinical Ward Round (CWR), as well as building on earlier work around use of Electronic Health Records (EHRs) during CWRs. As such, it extends earlier related work in use of EHR in Doctor-Patient Interaction; Use of Wearable Computers in CWR; Social Acceptance of Wearable Technologies, Hand Held Display in Healthcare, and Hybrid Display Systems. In this chapter, we review related work in each of these areas, identifying their limitations, and highlighting the research opportunity.

2.1 Electronic Health Record in Doctor-Patient Interaction

A clinician's ability to effectively interact with a patient is one of the key elements in providing high quality and effective care for patients. In addition, it allows the clinician to build rapport, earn trust, patient satisfaction and adherence [52, 56]. According to a report by National Research Council (NRC) [37], most of the existing EHRs are inefficiently used, mostly because of their poor design. The following are among the flaws of their design, human-computer interaction was not considered during design, they were

not designed to compliment clinician's needs and cognitive abilities and human factors were not considered [37]. It is crucial to consider doctor-patient interaction when designing EHRs. Results from a previous study indicated that clinicians eye gaze patterns with patient during consultation may have a key effect on the health outcome, satisfaction and perception of the clinician's affinity to patient [46]. However, it was found that use of computers could have positive impact on satisfaction of patient during encounter and also on doctor-patient interaction [34, 62, 64, 60, 33, 27]. The clinician's use of EHR also has a positive effect on the ability to share information between the clinician and patient [59].

The use of EHR also has its disadvantages, in a report by Shachak et al. [59]. The authors reviewed 14 articles, which were selected based on the criteria that they are within the 10 years prior to the publication and are related to the effect of EHR on doctor-patient interaction. It was found that use of EHR also had a negative consequence on a clinician's ability to focus on patients during visits. This was due to clinician's need to look up information from the computer, enter information into the computer while talking to the patient or while the patient is talking to the clinician. This could imply that the clinician is not ready to successfully convey compassion to the patient when it is important [3, 59, 7]. In addition, a previous study by Morrison et al. [48] also showed that most of the EHRs are designed for single users. As a result, it prevents effective collaboration between clinicians during CWR. Furthermore, the use of EHR negatively impacts patient-centeredness during consultations [59].

2.2 Use of Hand Held Display Computers in Healthcare

During the past few years, rapid improvements in technology has made it possible to develop computers that are more powerful, have higher storage capacity, faster processing power, portable, mobile, and lower energy consumption than their predecessors. Ranging from desktop, laptop to tablet computers and smart phones [53]. The advances in this technology has also enabled users to carry computers around anywhere, and the ability to use them at anytime with convenience. These improvements has also led to in-

crease in the rate of adoption and popularity of hand held display devices [26], such as tablet PCs, and smart phones.

Despite the increasing popularity of HHD computers in healthcare, clinicians are still reluctant to use them in their day-to-day work [25, 8]. A previous study by Grasso et al. [23] surveyed 366 medical students, collecting information about their use of HHDs, predicted use in the future and overall acceptance of the devices. They found that HHDs were mostly used for personal applications, they also reported that the adoption of the devices was not related to the user satisfaction. In other words, the less experienced clinicians were more satisfied with using the HHDs, while the more experienced ones were less satisfied. In addition to their results, participants predicted that in the near future, there will be a wider range of medical applications for HHDs and a significant increase in clinicians adoption of the devices.

Previous research by Strayer et al. [62] examined patient attitude towards clinicians' use of HHDs, such as tablet PCs in the exam room. They interviewed 96 patients immediately after a doctor's visit, the patients were asked about their perception about the doctor's use of tablet PCs. The result found that irrespective of patient's gender, age, ethnicity and work income, the overall patients perception of the use of HHDs by doctors was positive. Another research done by Vawdrey et al. [68], in order to assess how much patients knew about their inpatient care and how useful the HHDs were to them, they provided Apple iPad tablets to 5 patients with a prototype EHR application pre-installed. Their result show that patients were really impressed with the ability to access their own medical information on the tablet PCs.

Historically, EHRs have been more targeted at clinicians rather than patients. However, healthcare industry is increasingly transitioning from doctor-centric to patient-centric [68]. As a result, it is important that new systems are developed to provide interfaces that clinicians can use to share information with their patients at the patient's bedside.

Although, the use of HHD in healthcare has a lot of benefits, such as, access to clinical information, improved exchange of information, decision support, mobility and increase efficiency [42], their adoption in healthcare has been relatively low. Some of the potential reasons for their low adoption rate are, usability, distraction during doctor-patient interaction, and lack of properly designed applications [58].

2.3 Use of Wearable Computers in Clinical Ward Round

Ward round is a process that gives multi-disciplinary medical teams an opportunity to listen to the patient's concern, review patient condition and jointly come up with a coordinated plan of care for the patient. In addition, CWR offers great opportunities for effective doctor-patient interaction, sharing of information, building rapport and trust with patient [51].

Due to the complex nature of processes involved in patient care, introduction of electronic information systems continues to play an increasing role in all parts of delivery of patient care. Although, the introduction of these systems have generally improved efficiency and quality of services, they have also complicated a lot of existing processes. For instance, in a previous study [1], it was discovered that during the CWR, the process of retrieving, reviewing, and examining patient information, in addition to interacting with the patient, and making decisions all within a short period of time using a laptop or desktop computer was inefficient. It was also energy consuming, uncomfortable and could be perceived by patients as not showing concern to their problems.

Another reason why hospitals are not adopting the use of computers for information access during CWR is the need to use hands for examination and need for clean hands before examining a patient. Clinicians also prefer to focus on patients rather spending time on computers [1, 34, 71, 3]. As a result, patient information is often written down on a piece of paper, to be later transferred to the EHR post-CWR. Before the CWR, information is often printed out in paper form and carried along to the patient bedside. Furthermore, previous research also indicated that clinicians felt the existing processes of using laptop computers and paper notes, were inefficient and information was often lost between the beginning and end of CWR [36, 11]. However, the clinicians also indicated they were open to using newer technology or systems that will make the existing processes better [36].

Wearable technology has the advantages of being hands-free, portable, able to complement user's cognitive abilities, and can assist users in real time. The gadgets come in different shapes and types; glasses, watch, arm-band, and clothing as shown in Figure 2.1. Some previous work have also investi-

gated how use of wearable technologies could address some of the challenges outlined earlier [1, 36, 50, 13].



Figure 2.1: Different types of wearable technology gadgets, sourced from [55]

To find out how effective and useful wearable technology could be for clinicians in a CWR workflow, Adamer et al. [1] developed a system that utilised wearable technology. They recruited 9 doctors with 8 nurses from different medical backgrounds, with diverse years of experience practicing medicine. Each doctor was paired with a nurse. The doctor participants were asked to use a wearable system, which consists of a belt worn PC wearable technology called Q-Belt Integrated Computer (QBIC), shown in Figure 2.2, a radio frequency identifier (RFID) reader (for identifying patients), an accelerometer (for detecting gestures), and a Bluetooth headset (for results ordering using voice input). The nurses were given a personal digital assistant (PDA) for entering notes during the CWR.

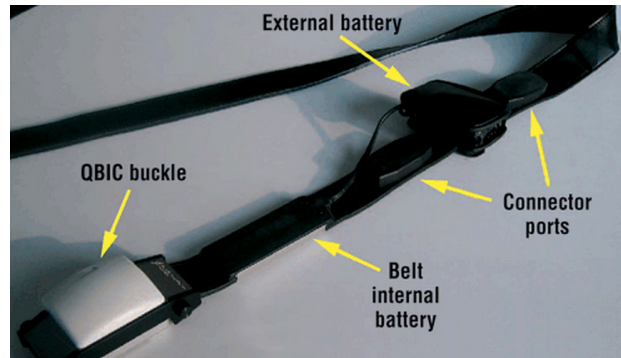


Figure 2.2: Q-Belt Integrated Computer, sourced from [43]

A real patient room was used for the test with a mannequin as patient, an RFID wristband was placed on the patient hand, a monitor on the bedside and a video camera was used to record the tests. On the patient bedside, the doctor used the RFID reader on his wrist to identify patients, which triggers relevant patient information to be displayed on the screen attached to the bed (also used as television). The doctor then uses the inertial sensor (accelerometer) on his wrist to control the application all handsfree. The bluetooth headset is then used to capture observations and order results for the patient. Figure 2.3 shows the scenario described above.

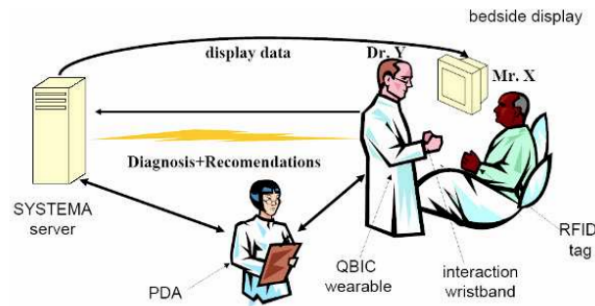


Figure 2.3: QBIC Scenario, sourced from [1]

The results from the tests indicated that most clinicians (doctors and nurses) responded that wearable technologies will make existing CWR processes smoother by enabling faster access to and up to date patient information,

increase efficiency, information sharing, and could lead to more standardised workflow and less paper work [36]. In terms of interaction between clinical team members, clinicians indicated that the more efficient the existing workflow becomes, the more time they will have available to work together and help each other [36]. As patient information is currently accessed using paper notes, it is often not a full picture of a patient's health record, because multi-disciplinary teams are involved in a patient care and as a result, parts of a patient file may be with a different specialist when the CWR process is going on [11]. Additionally, if new results are available for patient, the clinical team looking after that patient often do not know about it, until they go to a computer station and check.

However, some clinicians also raised concerns about the negative issues the use of wearable devices during CWR could introduce: Some doctors indicated that team work could be impeded due to the limitations of the system that was used for testing, as it does not allow the nurses to retrieve patient information, only the doctor could retrieve information [36]. It was also mentioned that use of wearable technology could create communication problems with patients [36]. Another doctor stated that everything worked currently in the existing workflow, as a result he did not want anything that would further complicate current ways of doing things. This, further indicates that systems in medical settings need to be properly designed, in order to streamline and not complicate existing processes. Furthermore, use of gestures as an input to the device was a concern for the clinicians, as they felt it will make them look weird performing gestures in front of patients [36, 1].

2.4 Social Acceptance of Wearable Technologies

Wearable devices have become more popular in recent years, with the launch of new wearable devices such as Google Glass™(GG) Head Mounted Display (HMD) computers, Fitbit™wristbands, Myo™armbands amongst many others. With technology advancing at a very fast rate, they are going to become even more portable, efficient, and effortless to use. To many users, these devices will make their day-to-day life easier by providing faster access to critical information, increased productivity, offer real-time assistance, but to

many others, they will be seen as a threat. In order to facilitate their adoption, it is important to design the systems to be easy to use, so that they can be embraced and acknowledged by target users [5]. A study of previous research will help in informing designs that avoid repeating mistakes made in the past that prevented adoption of these devices.

Buenaflor et al. [21] carried out a review of previous research that investigated the adoption and rejection of wearable computers, and came up with 6 human factors that played a key role in adoption of these technologies. The 6 factors lists were:

1. Fundamental needs
2. Cognitive attitude
3. Social aspect
4. Physical aspect
5. Demographic characteristics
6. Technical experience

We will only focus on one of them, which is the social aspect of the human factors in this section. The result of the study indicated that users willingness to use wearable devices is affected by the values and opinions of people around users, such as family and friends. According to Montero et al. [47], social acceptance can be divided into two different categories; first, 'User's social acceptance'; which is the overall impression a user has after using the wearable device for completing a set of tasks, this could be a favourable or unfavourable impression. Secondly, 'Spectator's social acceptance', which is the public's judgement or impression about the action of a user during the process of using the wearable device for completing tasks. The spectator has an opinion, be it awkward, crazy, weird, interesting, or making fun of the device user's action. According to Buenaflor et al. [21], 'personal privacy, social influences and culture' are the main factors that influence the social acceptance of wearable devices. Dvorak et al. [17] also mentioned other factors, such as 'transparency and attention in face to face interpersonal interactions', 'social politeness', 'reverence to personal space'.

The author looked at another study by Montero et al. [47] on social acceptance of gesture-based interaction, as gestures are usually used as a form

of input with HMDs [75, 14, 29]. The study listed some of the key factors that influence social acceptance of gesture-based interactions, namely; 'user's innovation adoption curve': In other words, there are different categories of users in terms of technology adoption, ranging from innovators to late adopters. This suggests that some users are more open to new technology than others. Secondly, 'culture and time': The length of time the device has been around and culture also affect the acceptance of a device, some devices may be more readily acceptable in some culture than others (for example, a study of US and Japan residents' satisfaction with different ways of interacting with an interactive high-definition television interface [65]). Also, the acceptance of the wearable devices may change over time, as people get more used to them. And thirdly, 'manipulation vs effect': In other words, the way a user performs gestures (manipulation) in a public environment where spectators are present, has a strong impact (effect) on their overall social acceptance of the device. The result of their study revealed that designing systems that need large gestures to interact with them, especially devices hidden from the public view is not advisable and such systems are more likely to be socially unacceptable [47].

Furthermore, in a previous study, Muensterer et al. [49] investigated the use of GG in a paediatric surgical practice. The participants used the GG in their day-to-day activities for four consecutive weeks at a Children's hospital. Their findings showed that overall people including nurses, participant colleagues, and parents all had a positive point of view towards GG. Many people were curious about the device and asked questions. Although, they reported that a few people were concerned that it is being used to record them without their knowledge. So this could mean that although there may be social acceptance issues with Google Glass in general use (eg by everyday people), there may be more social acceptance in some settings, such as medical.

2.5 Hybrid Display Systems: A Combination of Head Mounted and other Secondary Displays

Although, not widely used in a medical setting, there has been significant work previously done on the use of a combination of HMDs and Hand Held Displays (HHD)s. For example, in one research paper by Budhiraja et al. [10], an investigation was carried out to find out the benefits of using HHD as input devices for mobile AR applications viewed on an HMD. They recruited 12 participants for the study and found that using a HHD for input on a HMD in an augmented reality scene will be valuable in motion based input for widespread use in populated areas. It also found that tapping as a form of input on the HHD was a more preferable option than other methods, such as using the HHD device itself as a gesture for input.

Previous research also looked into how a combination of HMDs and HHDs could be used for an augmented reality remote conferencing application. The HHD was used as an input device. They came up with some design guidelines based on their findings, one of which was that a HHD should be used for input and the HMD should be used for viewing information or the environment [6]. In a different study by Feiner et al. [19], a prototype system was built that overlays textual information about buildings in a university campus through a see-through HMD and the user can use a HHD as a complimentary device for selecting menu entries, in order to view more information about what users see on the HMD as shown in Figure 2.4. However, it was only done for experimental purpose and as a result no analysis were carried out.



Figure 2.4: Prototype campus information system, sourced from [19]

Another previous research by Liu et al. [40], where a system was developed to investigate the advantages and disadvantages of using a combination of a HMD and a standard monitor display for monitoring patients vital signs in an operating room. As shown in Figure 2.5, an anaesthesiologist is using a HMD to simultaneously monitor vital signs while intubating a mannequin. The study found that, the use of HDS does allow anaesthesiologist to spend more time focusing on the patient rather than standard monitors alone, and it also helps them detect events faster when they are busy with the patient.



Figure 2.5: An anaesthesiologist intubates a mannequin while monitoring vital signs using a head-mounted display, sourced from [41]

2.6 Use of Google Glass™ in Healthcare

As a new wearable computing devices, GG has a huge potential in the medical domain. Although, lots of articles and reports exist on use of GG, there is little scientific research relating to its use in a medical domain. A search on Google Scholar¹ using the keywords "Google Glass Healthcare Medicine" only returned a limited number of articles [72, 2, 49, 12, 61, 44, 67]. The author believes that the GG has lots of potentials in medical domain due to its portability, form factor, and technical advancement.

In a study by Muensterer et al. [49], they investigated the use of GG in a paediatric surgical practice. The research participant wore the GG for four consecutive weeks at a Children's hospital, kept a log of all activities, its uses, disadvantages, and unexpected obstacles. Their findings showed that GG could be used for different medical tasks, such as, hands-free photo documentation and video recording the sterile environment of the surgery room, real time online search of complicated medical conditions, symptoms and diagnosis, and video conferencing. However, they recommended that before the beta version of the GG could be recommended for use in medical domain, it will need a significant hardware and software improvement. For instance,

¹www.scholar.google.co.nz

they suggested improvements to the GG camera, such as zooming: To allow surgeons focus on a specific region, and flash light: For optimal recording in conditions where there is insufficient lights. Other improvement suggestions were, an increase in the battery capacity, decrease in voice recognition error rate, reduced network lags and cut-outs, data privacy and ability to disable the automatic upload of data on the GG [49].

Another previous research on the use of GG in medical domain by Albrecht et al. [2], investigated the feasibility of using the device for documenting medical findings in forensic medicine. The researchers developed a software application that captures images of human body parts without using the hand to control GG. Then they compared the quality of these images with similar images captured using digital single lens reflex (DSLR) camera. Although, their findings demonstrated that GG was efficient for capturing for images used for forensic medicine documentation, the quality of the images was inferior in comparison to the ones captured using the DSLR camera. Also, they found that GG has a lesser battery capacity and consumes more power in comparison with DSLR camera. In addition, they found that the effort required to carry out the forensic procedure using GG was higher compared to the DSLR camera, as a result the duration is longer when using the GG [2].

Similarly, Widmer et al. [72] used GG for facilitating medical information search. They developed a GG software application that captures images and sends them along with an optional keyword to a content-based medical image retrieval system (CBIR), which is a database of images. The CBIR then queries its database using the image provided and the accompanying keyword to retrieve images with similar cases. To test whether the use of GG affects the accuracy of results returned by the CBIR, the test was carried done across three different conditions (MRI images from LCD monitor, images of the skin and printed CT scans and MRI images). Their results showed that adding keywords to the captured image improves accuracy of the results and also showed that the accuracy of the response from the CBIR were not significantly affected by GG. They also found that clinicians can simultaneously maintain contact with patients while retrieving information using GG. However, they raised some concerns about the disadvantages of using the existing version of the GG hardware, such as lack of auto-focus on camera, the short battery life and unstable Wi-Fi connection [72].

2.7 Doctor's Behaviour during Consultation

A previous study investigated how clinicians behaved while interacting with EHRs and its effect on patient care [3]. 10 clinicians with 3-10 years of experience with using computers during consultations volunteered to participate, 100 patients between the age of 18-65 years old were also recruited, 10 patients per clinician. A video analysis was conducted. From the data gathered, they identified three different styles of interaction used by clinicians;

1. **The human-focused clinicians:** Clinicians that spent most of the time during the visit interacting with the patient through verbal and eye contact and less time gazing at EHR.
2. **Technology-focused clinicians:** Clinicians that spent most of the visit time typing on a computer, gazing at the screen or trying to use the computer to carry out some tasks.
3. **Mixed interaction Clinicians:** In other words, clinicians in this group focused on the patient without using the EHR when talking to patient and also tended to interact with the EHR by focusing solely on it

The results also showed that irrespective of the interaction style used, clinicians still received a high satisfaction rating from patients, which may indicate that different interaction styles should be adopted while providing care for patient [3, 34].

Similarly, Booth et al. [7] investigated the skills that enable clinicians to effectively use computers during consultation. They observed 10 medical consultants and characterised them as either habitual or frequent users. Their findings also identified three different ways of using EHR: the controlling consultant who gives an indication to the patient not to interrupt during EHR use; the opportunistic/responsive who utilises the gaps during consultation to use the EHR; and the ignoring who is so focused on the use of EHR, as a consequence ignores the patient and loses rapport with them. Both findings show there is a similarity in the way clinicians use EHR during outpatient and inpatient consultations. It was concluded by the authors that, in order to be able to simultaneously use the EHR and interact with the patients effectively, consultants need to undergo specialised trainings. Otherwise, inattentiveness to patients and cognitive overload could have negative

consequences on doctor-patient interaction.

2.8 Limitations of Existing Research and Research Opportunities

The previous research has a number of limitations. First, it focused on investigating the use of new technologies, without considering the usability of the existing technologies in comparison with the new prototype systems under research. This is one of the novelties of our research, no previous study has compared the usability of paper-based, tablet PC-based (HHD), and a combination of HHD and HMD systems during CWR and their effect on doctor-patient interaction.

Secondly, previous research focused on investigating use of GG in surgical practice and testing specific applications on the GG device. No previous work has been done on investigating the usability of the device in HWR scenarios.

Thirdly, in terms of doctor-patient interaction during HWR, previous research investigated the use of devices such as, tablet PCs, laptops and desktop computers for accessing EHR. As a result, there is often a need for using gesture-based interactions, typing on the keyboard, or the need for prolonged gaze at the displays to access information. This limits the doctor-patient interactions. However, with the increasing availability of new HMD devices, such as GG, there is an opportunity to further explore how these devices can help improve doctor-patient interaction during CWRs. Additionally, tablet PCs could also be utilised to improve collaboration with patients, as patients could be shown their medical information on the devices and become more involved in their own care.

Finally, none of previous research on the use of GG during HWR has investigated the use of GG for accessing EHR application.

Chapter 3

Needs Analysis

In order to design systems that will support clinicians in their daily clinical ward rounds, it is important to understand the target users, what their work environment is like and how an interactive system could support them in their work environment. Having a good understanding of these is the foundation of requirement gathering, design and development. This process is called needs analysis and it is a key part of the user centred interaction design process.

To understand the existing challenges faced by clinicians during the clinical ward round (CWR) process, in this section the author followed the needs analysis process. Several observations of clinicians during the daily CWR were carried out by the author. The aim of the observation was to understand the CWR process, the activities involved, how clinicians collaborate and how they interact with their patients. Having a solid understanding of how clinicians operate in their natural working environment is an important part of the interactive design process, as it informs the design of the system.

3.1 Observational Study

At the beginning of the project two daily CWR observations were conducted at the Christchurch Hospital's General Medicine ward. The author shadowed the CWR teams, which consisted of medical doctors and nurses, although, there are other specialists involved in the process. Each CWR session was

about 2 hours long, an average of 10 patients were visited during the CWR. There were intervals in between each visit for carrying out other tasks, such as looking up laboratory results, previous history, and medications. The clinical team spent an average of 7 minutes at each patient bedside.

The aim of the observation was to identify the different people involved in the CWR process, how they collaborate, the CWR workflow and the different activities involved during the process. Based on the author's observation of clinicians during the daily CWR, the following section describes the existing CWR workflow and identifies the stakeholders involved. The author also created a list of requirements that the new system would need to fulfil in order to improve the CWR process, based on the findings from the observations, interviews and focus groups in subsequent sections. Note that, the process described below is based on the New Zealand system and may not necessarily be the same in other parts of the world.

3.1.1 Stakeholders:

1. Senior Medical Officers (Consultants): Senior doctors lead the team during the CWR. They are also responsible for reviewing the overall care of the patient.
2. Junior Doctors (Registrars/House Surgeons): They work as part of the team supporting the consultants by carrying out tasks such as taking clinical notes, ordering tests, or doing paperwork. They are still in training so they are sometimes delegated to be running ward rounds when the senior doctor is unavailable.
3. Trainee Interns: They are final year medical students. They mainly participate in the CWR as part of their learning and experience. They are allowed to do certain clinical tasks under supervision of the above doctors.
4. Nurses: They look after patients at the ground level. They care for the patient physically such as aiding their mobility, organising meals, delivering medications, updating patient current status on notes, coordinating ward cares from different services, and responsible for performing safety checks, and addressing any patient needs etc.

5. Multi-Disciplinary Team (MDT)/ Interdisciplinary Team (IDT): consists of social workers, occupational therapists, physiotherapists, dietitians, speech language therapists, and many others who contribute to overall patient's care. However, they often visit patients independently of the CWR team.
6. Carers/Advocates: They can be family members, friends, interpreters, or people employed solely for helping patients on bedside. They participate in discussions about patient's management plan and often take care of the patient's basic needs, such as feeding, giving medication, being a moral support etc.
7. Patients: These are people seeking care at the hospital. They are at the centre of care and are attended to by the clinical team during the CWR process.

It is worth stating that each group of ward round can include between 2-10 people. There are different factors that determine the number of people involved, such as, ward preferences, number of patients in ward, patient condition, people that are directly concerned with a patient's case, et cetera. The ward round is also usually attended by a senior doctor/consultant, a nurse and a trainee intern.

3.1.2 Current Workflow of the Clinical Ward Round:

The medical (as opposed to surgical) CWR consists of the following seven major stages:

1. Board Round
2. Ward Round Preparation
3. Paper Round
4. Bedside
5. Discharge Process
6. Debrief
7. Follow-up

Figure 3.1 shows a diagram representing the CWR process.

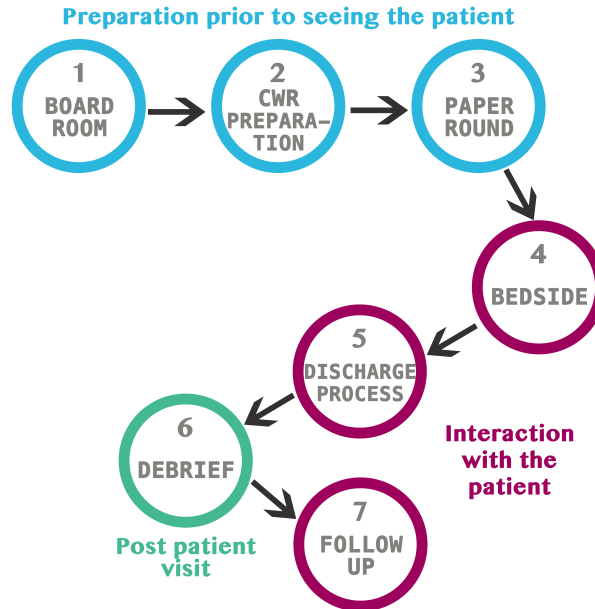


Figure 3.1: Clinical Ward Round Workflow

These are described in more detail below:

Ward Round Stages:

1. **Board Round:** Before the CWR starts, the clinical team meet in a room to have a brief overview of every patient in the ward. This consists of all of the people working with the patient, including senior doctors, junior doctors, trainee interns, medical students, nurses, nursing students, physiotherapists, occupational therapists, dietitians, social workers, etc. Jointly, they go through and give a brief update on the status of every inpatient currently admitted in a particular ward. The patient's name and other details, such as the team looking after the patient and discharge destination, are listed on the patient status communication board as shown in Figure 3.2. At this stage no detailed information about any particular patient is looked at, as it is a briefing session.

[illegible]

Figure 3.2: Patient Status Communication Board

- Clinical Ward Round Preparation:** The team then needs to ensure that all the clinical notes/records and other needed documentations are placed onto a trolley. They print any required documentation and place them in the clinical notes folder for each respective patient. At this stage, the list of patients they are planning to attend to during the day also gets printed and a computer workstation is set up so that the team can use it in between patient visits during the CWR. In Figure 3.3, a clinician leading the round is taking notes in the clinical notes document of a patient, while another clinician on the left is retrieving some other patient's folder from the cart.



Figure 3.3: Clinicians Retrieving Clinical Note from Trolley

3. **Paper Round:** The team talks about a patient prior to seeing him/her. They discuss things like what happened on admission, what happened last night, what are each team members plans for the patient so far, is the patient ready to go home, and what can be done to help the patient go home faster. Then the information gets synthesised to arrive at a diagnosis or tentative plans arranged for the patient in context.
4. **Bedside:** Meeting at the patient bedside, the CWR enables the team and the patient to build trust and exchange information. On arrival of the team, the senior doctor (consultant) greets, introduces the team to the patient, ensures patient dignity is respected by using a curtain to create a temporary private room and builds rapport with the patient. If the patient is already known by the team, the team reviews what

has happened previously, as well as the clinical notes of that particular patient. Then the senior doctor examines the patient, by measuring his pulse, blood pressure, etc. and aims to discharge. This bedside process is what this thesis mainly focuses on improving.

If the patient is newly admitted, or is a post-acute (Day 1 post admission) patient, the leading doctor reviews the clinical status and the patient history, and looks up information from the clinical notes. The doctor then synthesises the information and confirms details from the paper round with the team. The team then summarises their impression on the patient, that is, presumed diagnosis or differential diagnosis (when there is a margin of uncertainty). They then discuss the daily plans, what tests to order, what medications need to be changed or prescribed. They then plan what services are required, and communicate all of the above to the patient. Clinicians will also check the patient's understanding as a good and safe practice.

5. **Discharge Process:** This is a continuous process from the above. However on the day of discharge, the patient is reiterated when they will be going home, and what follow-up plans are in place for them. From a provider's point of view, this may mean organising extra tests as outpatient, giving out discharge prescriptions, writing letters to general practitioner (GP). From a patient's point of view, this might include advice to see a GP, and instructions related to work or driving or diet, etc. The junior doctor at this stage prepares the discharge summary, nurses organise discharge plan such as getting in touch with family members, arranging transport, making sure medications are ordered, while the multi-disciplinary team provides support post discharge at home. For example, home visits by nurses after discharge, medication delivery, equipment delivery, a safety review at home, etc.
6. **Debrief:** The team writes a summary for every patient and their plans for the day. Tasks are then allocated to respective team members, for example, order an x-ray for a specific patient. Sometimes, a written summary of the discussion is provided for the patient, issues arising from CWR are also discussed at this stage.
7. **Follow-up:** This stage is technically not part of the CWR, and is iterative. However, it is often done as part of the ward, as a result it is included here. At this stage when patient results are available,

clinicians take follow-up actions, such as prescribing new medications, stopping an existing medication, referring patient to a specialist, getting in touch with a family member and so on.

3.1.3 Clinicians Interviews

The CWR team works on a strict agenda with little time to spend at each patient's bedside. The clinical team needed to keep focus on the patient, consequently, the researcher did not ask the doctors questions in order to avoid disruption of the workflow, given time pressure already present. As a result, short retrospective interviews were conducted after each patient visit. In addition, other clinicians that showed interest in the study were also invited for interviews at later stages. In total, 11 clinicians from different medical backgrounds, such as paediatrics, surgical, emergency, and general medicine were interviewed, either individually or as part of a focus group. The author interviewed 6 doctors individually (4 senior doctors and 2 junior doctors) and had 2 focus group discussions with 7 doctors (some clinicians attended both the individual interviews and focus group discussion). This was done as part of the requirement gathering and getting to know the target users. By involving doctors in these discussions, it also ensures that they have a strong contribution towards the design of the prototype systems.

The clinicians were given pairs of Google Glass™(GG) Head Mounted Displays (HMD)s and Hand Held Display (HHD) tablet PC to become familiar with the devices, and were asked questions during the process. Questions such as the following:

1. Do they see any use for the devices in their day to day work?
2. What type of software applications do they currently use?
3. What are the existing challenges they face during the CWR process?
4. Are there other medical areas not necessarily related to their work where they think the devices could be used?
5. What type of information do they need at patient's bedside?
6. At what stage of the CWR do they need the information?

7. What is the overall patient satisfaction when using the existing paper method for accessing health information?

The aim was to gather as much information as possible; the sessions were recorded for later documentation with prior permission from the clinicians.

3.1.4 Focus Groups

For the focus group a similar process as the interviews was followed. The only difference was, rather than asking the interviewee questions one after the other, the questions were posed to the group and anybody could respond to the question. Additionally, in the focus group a lot of the clinicians talked about their specific domain, which made it a bit hard to synthesise all the information collected. The author moderated the discussion and avoided diversion from the question as much as possible. Similar questions were asked and the sessions were also recorded for later documentation.

3.2 Findings

This section describes the information gathered from the observational study, interviews and focus group discussions with clinicians.

3.2.1 Observation Feedback

The following outlines some of the observations made by the author during the CWR process:

1. At the patient's bedside all processes during the observation were still paper-based. Nurses/junior doctors take notes on paper and later transfer them to computer after the visit.
2. Clinicians do not necessarily know when a patient's laboratory or radiology results are available as there is no alert; they always need to look up the information on a desktop station prior to or after seeing a patient.

3. Senior doctors (consultants) do not record the patient's notes; they rely on junior doctors/nurses to take notes on paper. However, the senior doctors usually dictate to the junior doctors/nurses and requests for information from them.
4. Senior doctors (consultants) keep their hands free, because they use them for examining patients during CWR.
5. Senior doctors (consultants) focus a lot on the patient, in other words, there is a strong doctor-patient interaction.
6. All the patient information is not kept in a single place. Some patient information is kept in a folder. However, there is no guarantee all patient files will be available, as another clinician or allied health professional could have some of the patient files with them.
7. There are existing laptop computers available for use in different wards called COWS (Computer on Wheels) as shown in Figure 3.4. However, they are hardly used due to several reasons, such as, limited battery life, the risk of a privacy breach when moving them around the ward, an unreliable Wi-Fi connection, and poor usability for taking notes during CWR.
8. Patients do not see their results as they are normally checked by clinicians on a desktop station before seeing a patient.



Figure 3.4: Unused Computer on Wheel Laptops

3.2.2 Interview and Focus Group Feedback

Due to the similarity of questions asked during the interviews and focus group discussions the feedback for the both methods will be summarised in this section. The main topics raised were the following: perceived usefulness respectively of hand held displays and Google Glass, tele-medecine with Google Glass, learning and teaching using Google Glass and finally the use of devices to support decision-making.

Perceived Usefulness of Hand Held Displays

When clinicians were asked if they see any use for the devices in their day to day work, some clinicians indicated that some wards in the hospital have recently started trying out an application on tablet PCs (cortex) for managing clinical tasks. Although it is still in its early stages the feedback has been positive so far. Others thought it will be useful in their daily CWR sessions. For instance, clinicians will be able to access more up-to-date information about patients on the devices, such as the presenting complaint, past medical history, medication list, allergies, social information such as whether the patient is a smoker, past discharge summary and past health problem encounters.

It has also been mentioned that when a clinician is doing a procedure that he has not done before, or something he is not sure of, he could search information online, look up YouTube¹ for videos of procedures using the tablet PC. While waiting for a procedure he could also check his email for other important information. One clinician said, he believes tablet PC and GG can replace a desktop computer in what he does.

In response to the question, what are the existing challenges they face during the CWR process, clinicians complained about the overhead of having to transfer notes from paper to electronic health record during the CWR. A clinician suggested that on a day-to-day basis, tablet PCs could be used to record clinical notes and any encounters. Being able to see a quick reminder of patient information will be especially useful if you have forgotten about the patient you have seen previously.

Perceived Usefulness of Google Glass

¹www.youtube.com

Potential benefits of using the devices given are as follows: In primary care, GG could be used as an interface between the hospital and the GP. Other vital information could potentially be accessed from the GG. For example, patient allergies, adverse drug reactions or drugs under research. The GG could be used to capture photos of vital signs for patient monitoring, such as, skin rash and melanoma. In addition, it could also be used as a communication tool between healthcare workers, especially when they are doing a remote procedure and need help from other clinicians; they could use its voice input to communicate while their hands are busy. It was also suggested that GG could replace the pager because clinicians keep getting paged, and a lot of the time do not know who is paging them and how important it is.

One surgeon said, having the GG as a side view during surgical procedures would not be distracting based on his experience using the device. He added that he needs to have both his hands free, so it would be nice to have the device controlled using voice.

In acute medicine, they are investing in a device called Vocera², which is a wearable technology. This is a voice-controlled badge that you put tie to your cloth. People having the device can talk to each other. Just like the GG, it has the advantage of being hands-free. The Canterbury hospital has been trying to purchase it for some time, but there is a cost issue and the fact that the Wi-Fi within the hospital is not good enough.

One of the registrars present reported that there is an application called Cortex that was developed internally in the hospital. Cortex is a task manager run on iPad³. It integrates clinical information such as x-ray at patient's bedside, and also allows to assign tasks to another clinician. A notification is sent on the i-Pad as soon as the results are back. The registrar thinks this application saves them valuable time which translates into real savings for the hospital. He believes that a very good use of GG would be as an interface that allows to dictate patient information for example about discharge. He also thinks it could help reducing the needs for desktops; this would be very valuable especially since Canterbury hospital is going to become open plan and there is not enough space for desktops.

One of the senior consultant said "I go up to a patient and there is a proximity

²www.vocera.com

³www.apple.com/ipad/

device and says this is Patient Mr X and I will bring/download all the latest data on him, xray report, chest xray, a report, biochemistry, electrolyte, everything like that, there is an early warning score and then I can say pass this screen, woop its up there as well. That's going to be huge, that is what is going to come, there is no doubt about that. I think of the potential benefits of this is that a clinician can get a more detailed information on task at hand or current context". He added that, having said that, he believes it is a long way away as the health system does not have money.

Additionally, if there was a proximity sensor near the patient's bed, the clinician could instantly receive information about the patient on GG and be able to download all the patient's latest information when he visits him at bedside. "That is going to be the future of healthcare" said one of the senior doctors.

One of the clinicians sees GG as an enabler and a platform technology that has a strong potential. However he warns of a classic error being made in hospitals, where colossal sums of money are spent on a specific technology project with a very disappointing result. He took the example of a very pricey project where a paper-based document has been replaced by a soft copy. The problem is that, as clinicians don't always have computers handy they usually can't access this document when at the patient's bedside. As a result the clinician might not recall the information on the document by the time he is with the patient. In this case the paper-based document kept being used despite the new technology, as it more effective. This clinician insists on the fact that we have to think of GG as a technology enabler.

However, one of the clinicians mentioned that one serially processes information. As a result if for instance he is driving a car and wear a HMD he might be distracted by it if a notification comes up. This raises the concern of a cognitive issue while using GG.

Tele-medicine with Google Glass

Currently if a patient wants to have a quick follow up he would have to book an appointment to see a clinician in 2 weeks' time. This could be avoided through tele-conferencing, Skype⁴ (secure communication routes). This is especially convenient for people in remote areas such as Amberley, Templeton (Towns near Christchurch, New Zealand) and even people in rest

⁴www.skype.com

homes. It will be helpful to be able to communicate with them or their GPs; those are some of the things that can be done to avoid hospital admissions. For specialist consultations, doctors need some initial assessment, but for the follow-up they don't actually need to physically see patients given that there is enough skill in primary care.

One of the senior consultants added that she can see the tele-medicine working well in intensive care unit (ICU), but it would certainly have a much bigger impact if you could type and do things on a screen at the same time, while looking at other things. A possible scenario could be if a clinician having a video chat with a patient was able to access information on a secondary screen at the same time.

Intensive care paradoxically is the less innovative specialty in the world. There is no innovation in intensive care; the equipment that was used 30 years ago is still used today. The way things are done has not changed. However in acute medicine, if you've got nursing staff and registrars running around the ward with GG on, you would have the same characteristics of tele-medicine, also taking other programs on site. For instance, you could have a physiological data capture system for patients that are outside or inside ICU, and have an Early Warning System (EWS) score, which is basically a score related to respiratory rate, their blood pressure, temperature, urine output, heart rate, conscious level and airway.

Finally another clinician said that if a patient status notification could also automatically be sent to the GG including the patient's name, this could take you to the patient through someone else's eye; in other words, integrating current embryonic information systems in the hospital with telepresence. This way you could have all the patient results, the biochemistry information and everything else applicable on that patient.

Learning and Teaching using Google Glass

A clinician who works in the intensive care unit (ICU), said the GG device would be useful in a scenario where a registrar or house surgeon rings a senior doctor and tells the senior colleague that (s)he has a problem. Then on GG the senior doctor could see what the junior doctor sees. He added that in the ICU, they currently use very expensive USD20,000 cameras that they wear for such scenarios, but he thinks it is impractical to use them in most scenarios. Also with GG, doctors in remote locations can wear the GG and

collaborate by serially sharing the computer screen and patient information; still able to talk about the patient care.

Another clinician pointed out that GG could also be used as a teaching tool during surgery by broadcasting interesting surgeries to multiple hospitals, provided the patient has given consent.

There is huge medical advantage in wearing GG, as people can see what you are doing while performing procedures and it also allows to record those procedures. For instance, if you were recording with GG while performing a resuscitation, you could later on view the recordings and be able to notice valuable details about the procedure.

It could also be very useful for registrars to have access to a short video displaying the procedure they are supposed to perform, with the ability to use voice commands such as 'stop' and 'go back'. When doing intermittent tasks that you don't get to do frequently, having devices like tablet PC and GG that can guide you through those tasks will be very useful and handy. In summary, having something that is guiding you or someone helping you, while you are carrying out procedures might be useful.

Devices use as decision making support

Another clinician mentioned that such devices that are capable of capturing data and conveying what is around you to another device could be taken to the next step. Indeed the data gathered could be converted and used as a decision support tool. For example, a surgeon who had the patient's physiological score and other info about a patient would be able to use the data collected by the the device as decision support tool; he would be able to make future predictions based on previous experiences.

The interviews and focus groups were interesting and enlightening as they allowed the author to have a better understanding of the existing ward round process, an idea of what technologies the clinicians were used to, what they were expecting from technology and it also help understand how involved the clinicians are in their day-to-day work. It was indeed fascinating to see that most clinicians have ideas of ways technology could help them perform their daily tasks more efficiently.

3.3 Requirements

The field observations, interviews and focus group sessions resulted in the following set of functional and non-functional requirements for the prototype interface to be designed. The list presented below only shows the requirements needed for evaluating the use of a HHD and HMD systems in a CWR. Although a larger set of requirements were gathered initially, they were iteratively filtered, as not all requirements could be implemented given the scope of the project:

- **Unobtrusive:** The system should be small enough, in such a way that it does not attract too much attention from the patient or any of the clinical team members and it should not be distracting either.
- **Accessible Content:** The system should be able to display a variety of content to the clinicians, such as images (e.g past injuries compared to the patient's present condition, radiology results, lab results), texts (allergies, social history, demographics), audio recordings (past medical examinations), video recordings, charts, etc.
- **Input Interface:** The system should support typing, drawing, and voice input while still having the ability to interact with the system, enabling senior clinicians to use both their hands for physical examination. Preferably, it should not support gesture-based interaction, as it can be distracting, difficult to learn and perceived as crazy.
- **Sharing Content with Patient:** Ideally, the system should enable doctors to share information with patients on the screen. This will enable patients to feel involved in their care process and sometimes get a better understanding of their condition, such as x-ray results.
- **Collaboration between Clinicians:** The system should allow clinicians to share information with each other. Clinicians often need to discuss with each other relevant patient information before making decisions. Having the ability to easily share information will enable better collaboration among them.
- **Hands Free:** The system should allow the leader of the CWR (usually the senior doctor) to be able to use it without the device getting contaminated during the physical examination of patient. In other words,

when the senior doctor is examining the patient and his/her hands get contaminated, there should be no possibility of spreading the contamination further.

- **Portability of Devices:** Physically, the device should be portable enough to use and move around. This is necessary as clinicians are always moving around during the CWR workflow.
- **Ease of Use:** The system must be easy to use with minimal steps required to achieve a task. This is very important as the aim of clinicians during the CWR process is to take care of patients rather than using computers. To be effective the usability of the system should be very good. Additionally, if the system is more complicated than existing processes, and if distracts the clinician by requiring him/her to gaze at the screen for too long during the CWR, then it is very likely to be rejected by the clinicians.

Chapter 4

Design

4.1 User Centred Design of Solution

In this section, the author describes the design of the prototype that will be deployed for the clinical ward round (CWR) experiment trial. The target end users of our design activities are the clinicians. Therefore, in designing the prototype, the author took into account the feedback received from clinicians during the CWR observations, interviews and focus groups as discussed in the previous chapter.

Based on the requirements gathered in the previous chapter [3.3](#), the author believes that the HHD and HMD devices can be used to satisfy the requirements. Both devices are portable, easy to carry around, and can be used to access digital content. The HHD has a reasonably large screen that can be used for sharing information with patient at the bedside, it also allows different types of input such as, drawing and typing. In addition, it supports web applications, which can be used for building easy to use interfaces. The HMD (GG) has advantages such as, handsfree device, voice input, different type of content is accessible on it as well.

A key purpose of the prototype system is the ability to use it to access information on a Hand Held Display (HHD) and/or a Head Mounted Display (HMD) during a CWR, without interfering with doctor-patient interaction. The main technologies used are a HHD, which is an android based tablet

PC, as shown in Figure 4.1b, and a HMD, which is a Google Glass™(GG) wearable device, as shown in Figure 4.1a, both devices are connected to the same wireless network in the hospital.



(a) Google Glass™Head Mounted Display, sourced from [73]



(b) Samsung Tablet PC Hand Held Display, sourced from [57]

Figure 4.1: Head Mounted and Hand Held Displays

To approach this design process the author uses a User and Task centric design methodology. By taking into account the various tasks clinicians are expected to carry out during the CWR, a system can be designed around facilitating the expected end goals. With this iterative design approach, we can address their requirements, as well that of other stakeholders. In every iteration of the prototype, the system was tested by getting subjective feedback about its perceived usability in order to ensure a useful and realistic final prototype was developed for the final evaluation. This experiment will provide empirical data that can be used to analyse the HHD and HMD in terms of their usability, obtrusiveness, support for doctor-patient interaction and functionality, as well as gain information on the appeal of the prototype interface.

After going through the feedback received from the interview of clinicians, patients, and the information gathered through observation during the requirement gathering, we came up with an idea of what an ideal HHD and HMD prototype system is that could be used to facilitate the CWR process. The idea is that, since clinicians will like to be able to collaborate with each other during CWR, the HMD and HHD could be used to share information between them. In addition to this, clinicians don't like getting distracted when interacting with their patient, so having a device that allows them

to have minimal distraction could be valuable to them. In addition, since desktop computers and laptops are not feasible due to the immobility in comparison to the HHD, HHD could help clinicians share information with their patients more easily. Both devices are also portable, and relatively easy to use. By using these state of the art technologies, tablet PC (HHD) and GG (HMD), an easy to use prototype system could be created using several web technologies that will help improve the CWR process without having a negative effect on doctor-patient interaction.

Figure 4.2 shows one of the scenarios the prototype was built for. The consultant leading the CWR wears a HMD GG and the junior doctor/nurse uses a HHD tablet PC. On the patient bedside, the junior doctor/nurse uses the HHD to look up the patient information, show patient their results and can also push the information to the HMD for the consultant/senior doctor to see if preferred, this allows the consultant to get an immediate overview of all important information about the patient, such as patient demographics, allergy information, family history, social history, etc.



Figure 4.2: A ward round session using hand held and head mounted display interfaces

It is worth noting that in this experiment, we only focused on some of the CWR tasks, such as:

- Accessing patient information.
- Sharing patient information.
- Performing patient examination.
- Recording examination details.
- Diagnosing patient.

It should also be noted that, there are many other tasks involved in a CWR process. However, in this thesis, our focus is on the above listed activities. Considering, these are the main activities that are carried out on the patient bedside and the ones that involve patient interaction during the CWR process.

The following sections describe the design iterations that were carried out in details.

4.2 Low Fidelity Prototype Iteration

The overall goal of the low-fidelity prototype was to try out some basic user interface and interaction designs on specific parts of the CWR workflow mainly using paper sketches. Firstly, the author wanted to introduce the initial ideas of what the interfaces on both devices (tablet PC and GG) will look like to the clinicians that are potential users of the interfaces. Secondly, we wanted to find out to what extent the initial interaction design supports the actual CWR workflow. Thirdly, we wanted to validate our understanding of the existing CWR process, its limitations and ways it can be improved using the interfaces. Fourthly, the aim was to have a better understanding of how clinicians leading the team (senior doctors) during CWR and their assistants (junior doctors/nurses) can collaborate in an efficient way. Lastly, to provide low cost implementation of the prototypes that could be tested with potential users.

The prototypes were created using papers, multiple sheets of A4 papers were used to represent different screens of the proposed system. Figure 4.3 shows the main menu of the application, the user can navigate to other pages from main menu by selecting any of the menu widgets. As an example, if the

user wants to enter patient notes during the CWR, the user selects the notes widget which triggers the notes page, as shown in Figure 4.4, on clinical notes page the user can then enter information into text area.

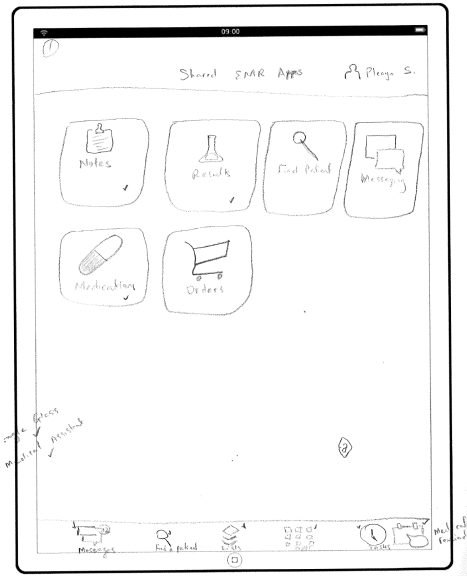


Figure 4.3: Main menu of the Prototype Application on Tablet PC

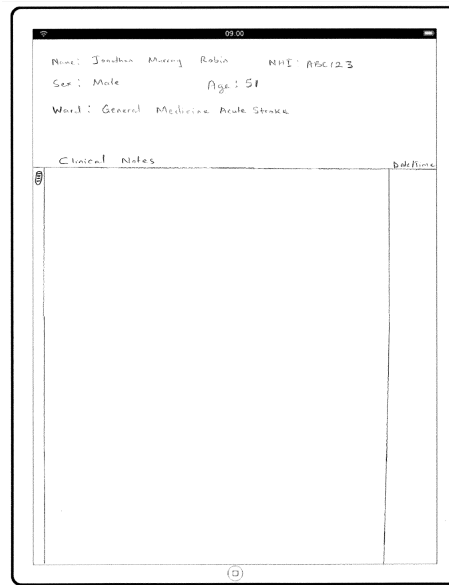


Figure 4.4: Clinical Notes page the Prototype Application on Tablet PC

Similarly, if the user wants to view patient medication list, they select the Medication widget from the main menu, which then triggers the medication list page, as shown in Figure 4.5. In addition, if a user wants to view results associated with a particular patient, they can select the results widget from the main menu, which navigates the page to the results page, as shown in Figure 4.6. Note that the results page is the only page that shows the patient demographic information, also note that it has three buttons (Medication Chart, X-rays, and Clinical Notes) for each result in the list.

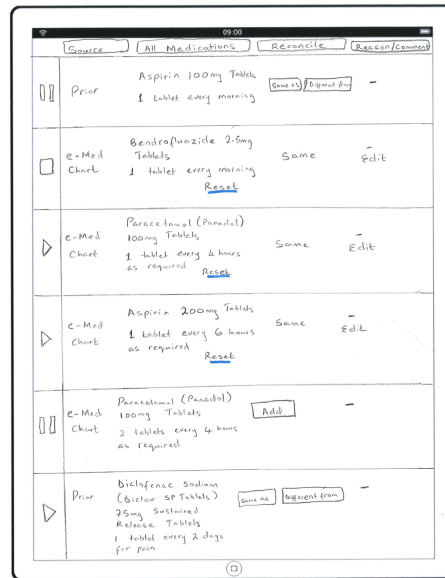


Figure 4.5: Medication List on the Prototype Application on Tablet PC

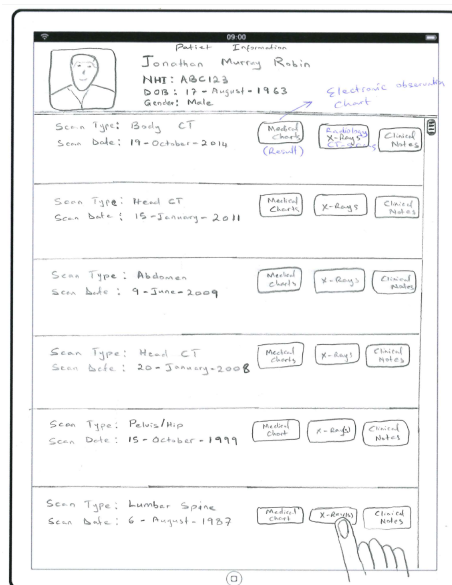


Figure 4.6: Patient Results on the Prototype Application on Tablet PC

When the X-ray button is pressed, the page navigates to the X-ray/CT Scan

page, as shown in Figure 4.7. There is another sketch in Figure 4.8, this was the initial sketch of what the cards/views on the GG were supposed to look like. However, there was no reference to any GG related functionality on the other sketches.

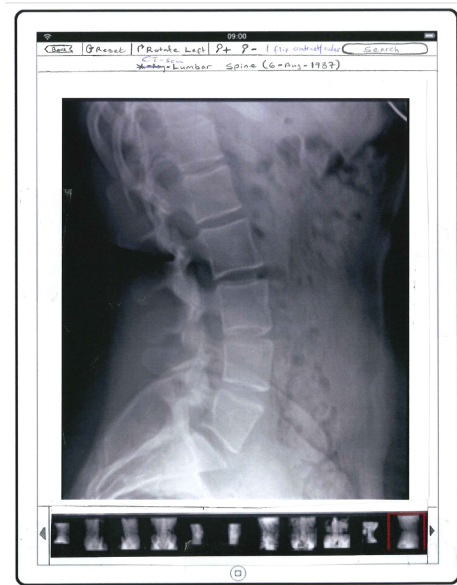


Figure 4.7: Patient CT Scan on the Prototype Application on Tablet PC

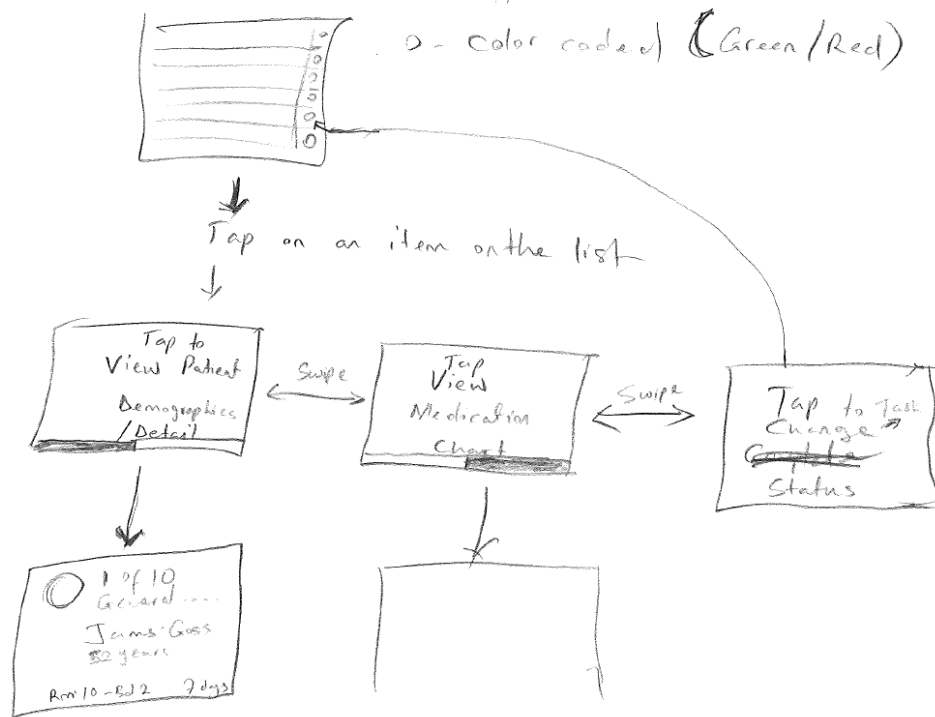


Figure 4.8: Cards on the Prototype Application on Google Glass™

Lessons Learned from Testing the Low Fidelity Prototype

To test the low fidelity prototypes, the author asked a friend who was a user experience designer to test the interfaces, a former doctor now software engineer working for a health IT company was also one of the testers of these prototype interfaces and a senior medical registrar at the Christchurch hospital. In total, three people from different backgrounds were involved in evaluating this version of the prototypes.

- Patient information displayed on GG HMD should be as minimal as possible.
- There should be a way of pushing information from the HHD to the HMD.
- Some of the information shown in the HHD prototype are not rele-

vant on patient bedside during CWR, such as, the orders widget, and messaging.

- On the HHD interface, the medication list is confusing and the different widgets on the screen are not self explanatory.
- The interface on the HHD should be very easy to use and there should be a minimal number of clicks required to get stuffs done.
- The input interface on the HHD should be in chronological order.
- The GG HMD interface was confusing.
- How to interact with GG was not intuitive enough. It should be clearly explained to potential users of the interface.

4.3 High Fidelity Prototype

After receiving feedback from a couple of clinicians and a couple of experienced user interaction experts, about the low fidelity prototypes, the author redesigned the system to take into account the lessons learnt from evaluation of the low fidelity prototype.

A wireframe application, UXPin ¹ was then used to create a more realistic version of both interface prototypes. Figure 4.9 shows the landing page of the HHD interface, which has a six different buttons, the user can use the buttons to navigate to other parts of the application from main menu by selecting any of the menu buttons. As an example, if the user wants to find a particular patient on the HHD interface, the user can select the Find Patient button which will trigger patient list view, as shown in Figure 4.10.

¹www.uxpin.com

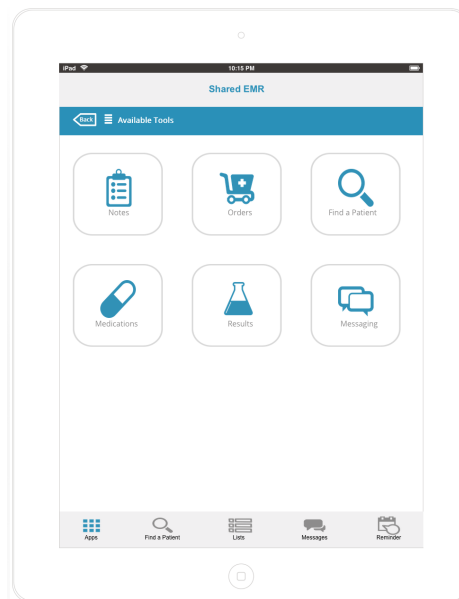


Figure 4.9: Main menu on the Tablet PC for High fidelity prototype

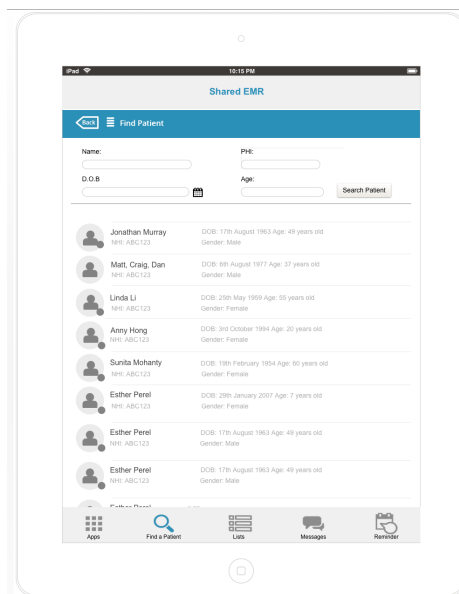
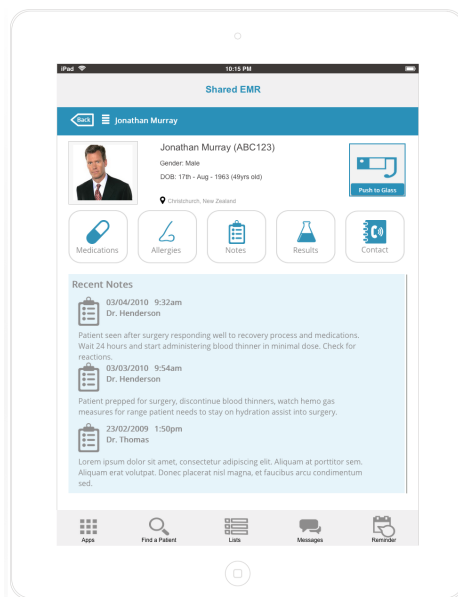


Figure 4.10: Patient list view on the Tablet PC for High fidelity prototype

Once the user is on the patient list view, they can search for the patient they are interested in either using the name, date of birth, patient identifier, or age. Selecting a patient from the list navigates the view to the patient overview page, as shown in Figure 4.11a. At the top right of the page, there is a button that allows users to push the patient demographic information onto the HMD interface (GG). The user can view other patient information from the patient overview page, such as patient allergies, which looks like Figure 4.12a



(a) Patient Overview on Tablet PC

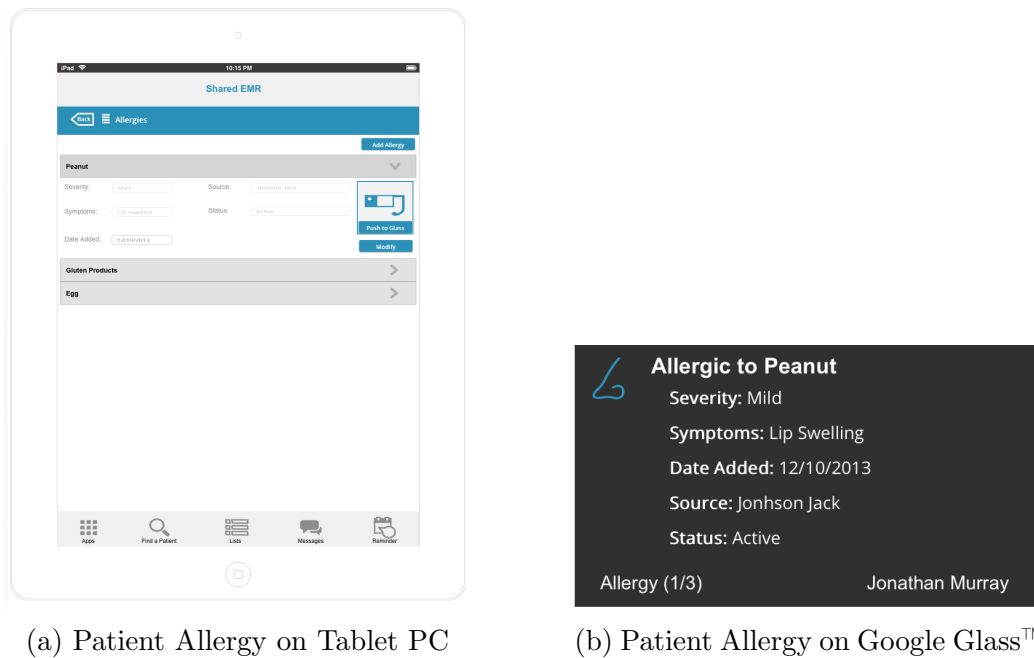


(b) Patient Demographics on Google Glass™

Figure 4.11: Patient Demographics on High Fidelity prototype

On the GG interface, the patient demographics look like Figure 4.11b. For other patient information like medications, the user can scroll across a timeline-like set of cards to view all the medications using the GG touchpad as input. Figure 4.12b shows an allergy view on GG.

Also, note that there are other information such patient medication, results, notes that could also be accessed from both interfaces patient overview page.



(a) Patient Allergy on Tablet PC

(b) Patient Allergy on Google Glass™

Figure 4.12: Patient Allergy High Fidelity Prototypes

In addition, the high fidelity interfaces allowed users to interact with them unlike the low fidelity version of the prototype. Also note, that the GG interface mock up was designed to be viewed in a browser rather than on the actual HMD device. This enabled clinicians to have a full view of the flow of information from one device to the other. Again all medical data was fictitious.

Two senior doctors were presented with the newly improved high fidelity version of the prototype and their feedback were as follows.

- Clinicians should be able to access the following information; patient demographic information, presenting complaint, past medical history, medications, allergies, social information, results, problem list, plan, quick reminder about patient.
- Junior doctors should be able to annotate on pictures their senior counterparts took using the GG HMD during the CWR.
- It was again suggested that some features were not needed, such as,

the list and reminder menus at the bottom of the tablet PC prototype. So the author took them out in the final design.

- A context of the patient should be kept on each page. In other words, a clinician should have an idea of the current patient irrespective of the page they are currently looking at on the tablet PC and the HMD. For instance, in the high fidelity version of the prototype, when viewing the patient allergies, the patient context is lost.
- Both clinicians said they like how simple the interface looked.
- They said it was easy to use even for a beginner.
- The location of the patient was not needed as it is not used.
- One of the clinician was very impressed that the patients have pictures, he explained that having pictures it made the patient look human again. In current systems, patient pictures are often not present. They also usually refer to patients using their bed numbers, codes and other forms of identification, but rarely by their names.

4.4 How Design met Requirements

In this section, the author briefly describes how the prototype system that was developed took into account the feedback from clinicians and how the requirements gathered in section [3.3](#) were met.

In terms of the unobtrusiveness, the HHD tablet PC was designed to be used by the junior doctor during the CWR. This will enable the senior doctor to focus on the patient, while information is retrieved by the junior doctor. Additionally, the senior doctor has the option of getting information pushed onto the GG HMD from the tablet PC. The HHD Tablet PC acts as the primary interface for retrieving information, as a result, the prototype interface on the tablet PC was designed to be able to easily display different types of contents, such as, images, text, video recordings, etc.

In addition, the interface on the tablet allows a junior doctor to easily type information into the system. This also prevents the senior doctor from getting distracted and also allows them to remain hands free, so they can examine the

patient when the need arises. Because of the portability of the tablet PC and the size of its display, information, such as x-ray results can be easily shared with patients on their bedside. In terms of collaboration between clinicians, the prototype's combination of the HHD and HMD interfaces during the CWR could help clinicians collaborate better, by allowing information to be shared easily across the devices between clinicians. Also, in scenarios where the HMD is not used, clinicians could easily look up information together on the patient bedside, with the junior doctor using the device.

Furthermore, both devices (HMD and HHD) are more portable and easier to carry around in comparison with the existing interfaces, such as, paper folders, computer on wheels laptops and desktop computers. The prototype system that was developed also took ease of use of the different interfaces into consideration. As an example, any information on the interface could be retrieved with no more than five clicks, the user interface was designed to be very simple to use and navigate around. However, with the HMD, there were some limitations in the user interface design due to the unique styles GG has that software developers have to follow [22].

Chapter 5

Implementation

5.1 Final Prototype Implementation

Based on the lessons learnt from evaluation of the low fidelity and high fidelity prototypes, final prototypes were designed and implemented. In this section, the author outlines the main functionality and implementation details of the final prototypes to be used during the experiment's trial.

The final interface prototype on the tablet PC has two main views, which are the 'Find Patient' and 'Patient Info' views. The 'Find Patient' view, as shown in Figure 5.1a, is the main page of the HHD interface. It allows a clinician to easily search for a patient, by entering any of his first name, family name, date of birth or the patient identifier into the search input field as annotated in the figure. The application then filters the results and shows only the patients that match the search criterion. In this case, it only shows patients that have 'ke' as part of their names. Figure 5.1b also shows an unfiltered version of the patient list. The user can also easily scroll up or down the page to visually find a patient.

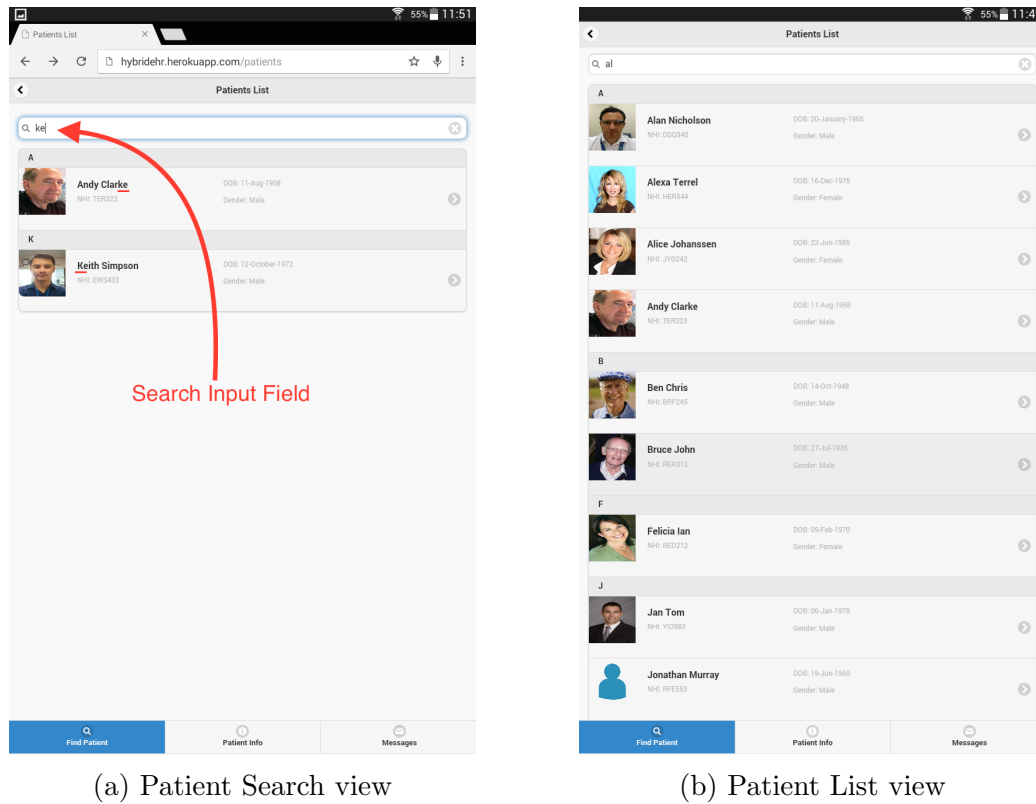


Figure 5.1: Application Landing Page

Once a clinician has found the patient of interest, (s)he can tap on the patient's name from the list. Doing so, will navigate the screen to the selected patient's information page, as shown in Figure 5.2. From the information page, a clinician can access all patient information needed on the patient bedside during the CWR, such as patient demographic information as shown in the figure. Also note, on the right hand side of the demographic information, there is a button with a glass icon and text 'Push to Glass'; this is an additional feature that allows the demographic information to be shared with the HMD (GG) interface that has been pre-paired with tablet PC. From the same information page, a clinician can scroll across the buttons (bi-directional lines in green) to access more information about the patient. This horizontal menu section contains the following buttons: clinical notes, general practitioner's Referral, Presenting Complaint, Medication, Allergies, Past Medical History, Family History, Social History, Observations, Results,

Plan, Impression, Fluid Prescription, and Drug Treatment buttons.

When a clinician wants to view a specific information for the selected patient, he can press the button representing the information. Doing so, brings up a collapsible list of that particular information. As an example, if the clinician wants to see the referrals for patient Keith Simpson, he presses the button annotated in blue square in Figure 5.2, this brings up the patient's general practitioner's referral message, as shown in the same image.

For the GG interface, if the senior clinician is wearing the HMD and would like to get the some information about a patient sent through through, the junior doctor using the HHD interface can use the glass-icon button in the referral message to push the specific information to the GG interface. Once the information has been successfully pushed, the junior doctor will see a brief pop-up message on the HHD interface indicating success, which disappears after a few seconds. On the GG interface, the senior doctor hears a beep sound when the information arrives, immediately (s)he looks up at the GG display, the information is presented, as shown in Figure 5.3. Note that on the GG interface, the clinician can see what type of information was pushed and how long ago it was sent across.

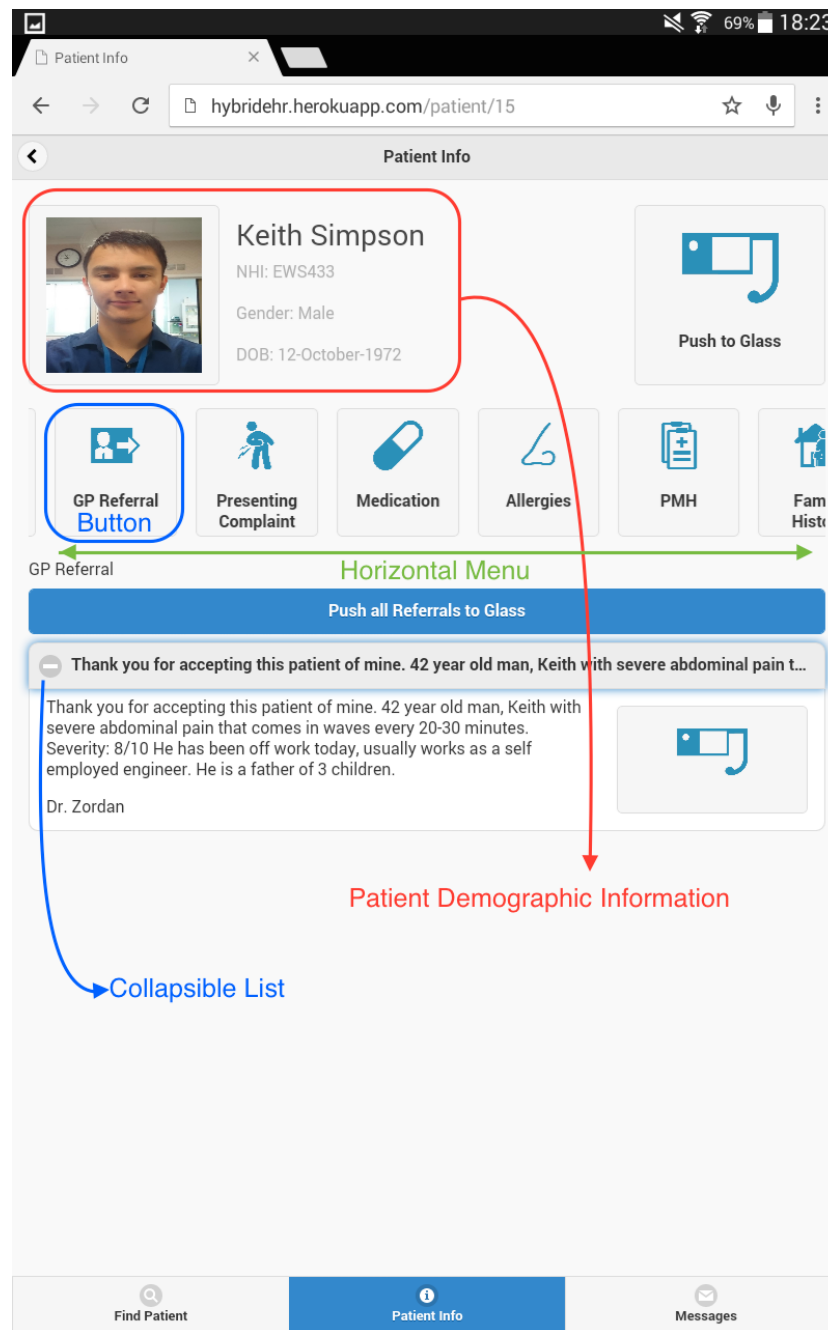


Figure 5.2: Patient Referral view on Tablet PC

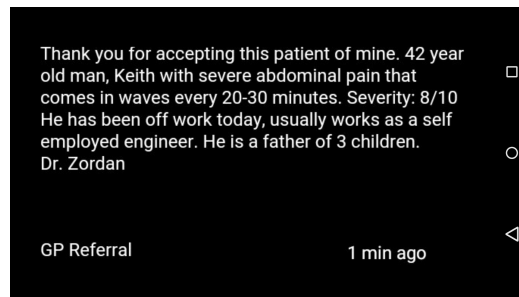


Figure 5.3: Patient Referral view on Google Glass™

In addition, the junior doctor can enter notes on the tablet PC by selecting the notes button from the menu bar. Doing so will present a text input field, as shown in Figure 5.4a which allows entry of clinical notes information. Upon completion, the notes can then be saved into the system by pressing the Save Notes button. It is also worth noting that, results such as urine test, blood count, radiology can be viewed on the tablet PC, as shown in Figure 5.4b. However, the option to view results was not included in the GG design due to the limitation of its display size. To view more screens of the final prototype, please refer to Appendix D.

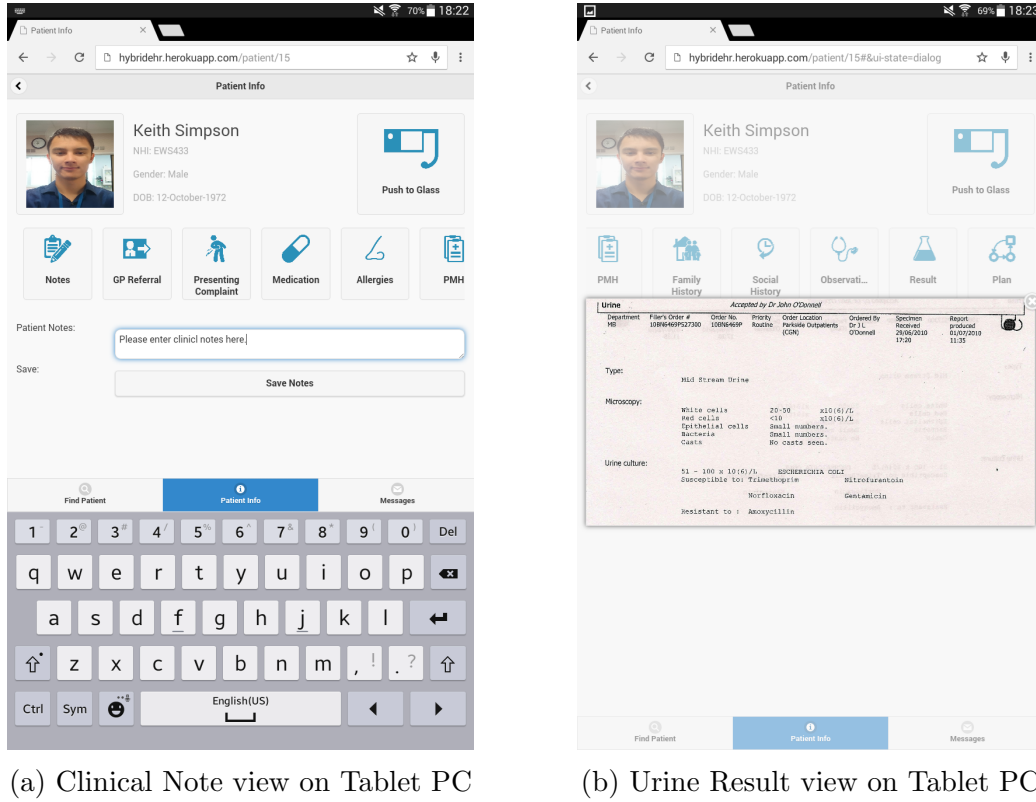


Figure 5.4: Note and Result views on Tablet PC

5.2 Implementation Details

In this section, we talk about the technical implementation details of the prototype system and the different technology stack that were used to implement the system. The author named the prototype system Hybrid Electronic Health Record (HybridEHR), it consists of a Samsung Galaxy Tab 4 tablet PC and a Google Glass™(GG) both running on an Android OS.

5.2.1 System Architecture

Figure 5.5 shows a high level overview of the system architecture of the HybridEHR system. The final prototype consists of three different subsystems

that interact with each other, as follows:

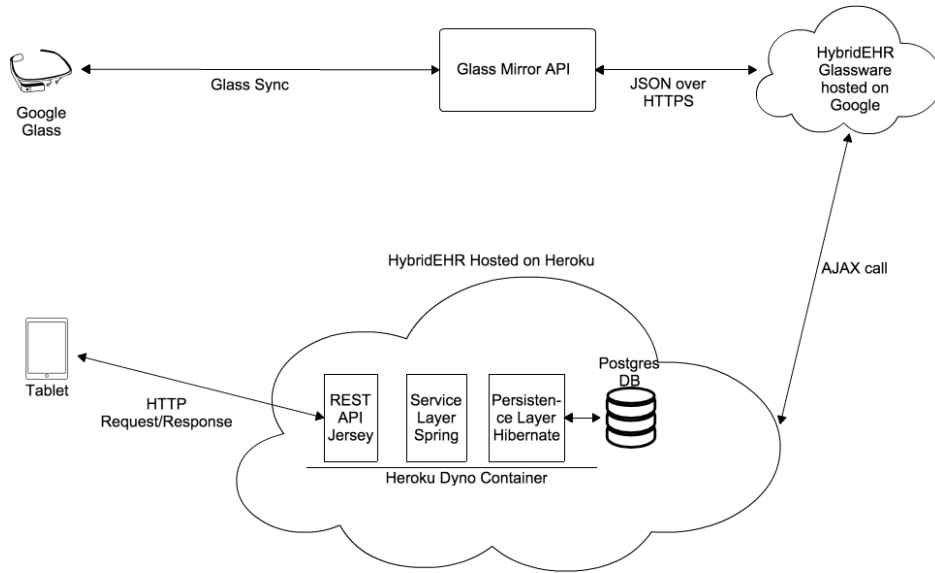


Figure 5.5: System architecture of the HybridEHR

- Hybrid EHR Web application:** This is a web application that uses a model-view-controller (MVC) architecture [32]. MVC enabled separation of concern and made the application easier to extend when new features were being added to it. As shown in Figure 5.5, the application uses a Postgres database ¹ to store all patient information. The HybridEHR is hosted on Heroku cloud application platform ², so it can be accessed and managed from anywhere. It exposes a web interface (more details later) so it can be directly accessed through a web browser, and also exposes a REST [20] (Representational State Transfer) API (Application Programming Interface) so other applications can access it. In addition, this application is also responsible for pushing the patient information to the Glassware using asynchronous javascript (AJAX) calls.
- Mirror API:** The mirror API ³ is a set of cloud based RESTful services provided and managed by Google. The services enable application

¹www.postgresql.org/

²www.heroku.com/

³www.developers.google.com/glass/develop/mirror/index

developers to build Glassware by interacting with these services and it does all the interaction with Google Glass™. As a result, no code is required to be deployed or run on Glass directly by developers. In addition, the services are platform independent. As shown in Figure 5.5, the author used the Mirror API in the implementation of the prototype system to send the patient information to GG. Using the mirror API makes building application faster and allows applications to be built for GG without using the native Glass development approach.

- **HybridEHR Glassware:** Glassware⁴ is the terminology used to describe applications that are designed to work with GG. In the prototype system, the author implemented a glassware application as a Java Enterprise Edition web application hosted on Google App Engine cloud platform⁵. The responsibility of the glassware is to parse and format the patient information payload sent from the tablet PC (HybridEHR application) into a hypertext markup language (HTML). The formatted data is then forwarded to the Mirror API, which in turn sends the content to GG as timeline cards (in GG the information is presented in a timeline-like interface on the screen).
- **Front End/Web Interface Implementation:** The user interface of the web application was implemented using HTML for markup, Javascript for the logic and JQuery Mobile library⁶ for styling. The author also used two main colors, white and blue. One of the reasons for choosing blue is because, previous research shows that using a primary color when designing an interface enhances the development of users mental model and signifies simplicity [74]. In addition, it has also been found that blue color boosts creativity and is associated with reliability, and safety. While, white color is used to communicate clarity, simplicity and efficiency [15].

⁴www.developers.google.com/glass/

⁵www.cloud.google.com/appengine/

⁶www.jquerymobile.com

5.3 Hardware

5.3.1 Hand Held Display

The hand held display device that was used is a tablet PC by Samsung. The Samsung Galaxy Tab 4 10.1 ⁷ runs on Android tablet with a 10.1" IPS (In-Plane Switching) screen, it has a resolution of 1280 by 800 pixels. It also comes with 16GB of internal memory, 1.5GB of RAM, and a microSD slot for an additional 64GB of memory. In addition, it features Wi-Fi and Bluetooth 4.0. Control of the device is accomplished mainly by using fingers on the screen. The author decided to use this tablet PC because it is relatively cheap, light, comfortable to carry and easy to use. For full specification of the tablet PC, please see Appendix [A](#).

5.3.2 Head Mounted Display

Google Glass^{TM8} is an optical head mounted display that features a prism in front of the user's right eye, a camera capable of recording videos with 720p and capturing images at 5 megapixel, a bone conduction speaker for voice input and control, a rechargeable battery and a touch pad on the right side of the frame for controlling it, as shown in Figure [5.6](#). It also runs on Android operating system. In terms of connectivity, the device has an inbuilt Bluetooth and a Wi-Fi for connecting to the internet and other devices. For full specification of the Google GlassTMHMD, please see Appendix [A](#).

GG offers an opportunity to uncover new ways of easing the work of clinicians and potentially improving interaction between patient and clinicians in the medical domain.

⁷www.samsung.com/us/mobile/galaxy-tab/SM-T530NZWAXAR

⁸www.google.com/glass/start/

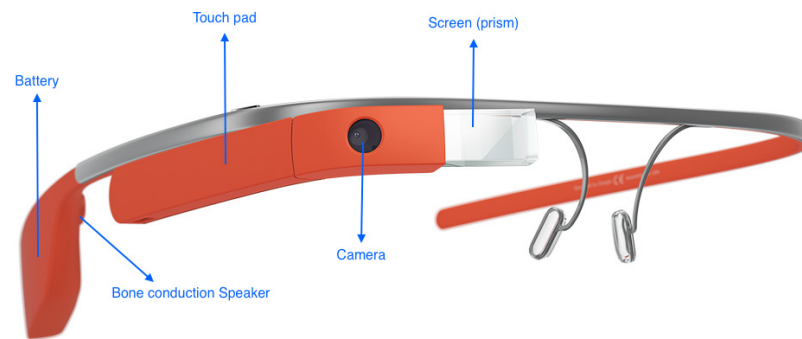


Figure 5.6: Google Glass™

Chapter 6

User Evaluation

The purpose of the evaluation is to enhance parts of the interface with which users come into contact, understand how clinicians perceive the interfaces before, during and after interacting with it. In this chapter the author present the goals, tools, scenarios, participants information, and pilot testing information. The process described in this chapter is important for investigating how clinicians perceive the interfaces before, during and after interacting with them.

6.1 Research Questions

1. Are Hand Held (HHD) and Head Mounted (HMD) Displays useful to clinicians during clinical ward round (CWR)?
2. Is there any difference in the ability to perform tasks at the patient's bedside across the three different interfaces (paper, hand held display and head mounted display) during CWR?
3. Is there a difference in how comfortable clinicians felt while interacting with patients across the three different interfaces?
4. Which interface is the least distracting and the most distracting for clinicians at the patient's bedside?

5. Is the doctor's focus on patient affected by the use of different interfaces during patient encounter?

6.2 Evaluation Goals

- Investigate the usability of a Hand Held Display and Head Mounted Display systems during doctor-patient encounter in CWR.
- Investigate whether a HHD, such as a tablet PC and/or HMD, such as Google Glass™(GG) can improve doctor-patient interaction in comparison with existing paper-based method for accessing patient information during CWR.

6.3 Experiment Setup

For the evaluation, a room was set up to simulate a patient bed, test the prototype and get feedback from the participants. The installation in the room included a bed, a mattress, a pillow and a bedsheet for patient participants to lie on during the trials. There was also an oxygen mask, required for one of the scenarios, as shown in Figure 6.1, a Google Glass™ for senior doctors, a tablet PC for the junior doctors for use during HHD and HMD scenarios, three set of paper-based clinical notes folders for use during the paper scenario.

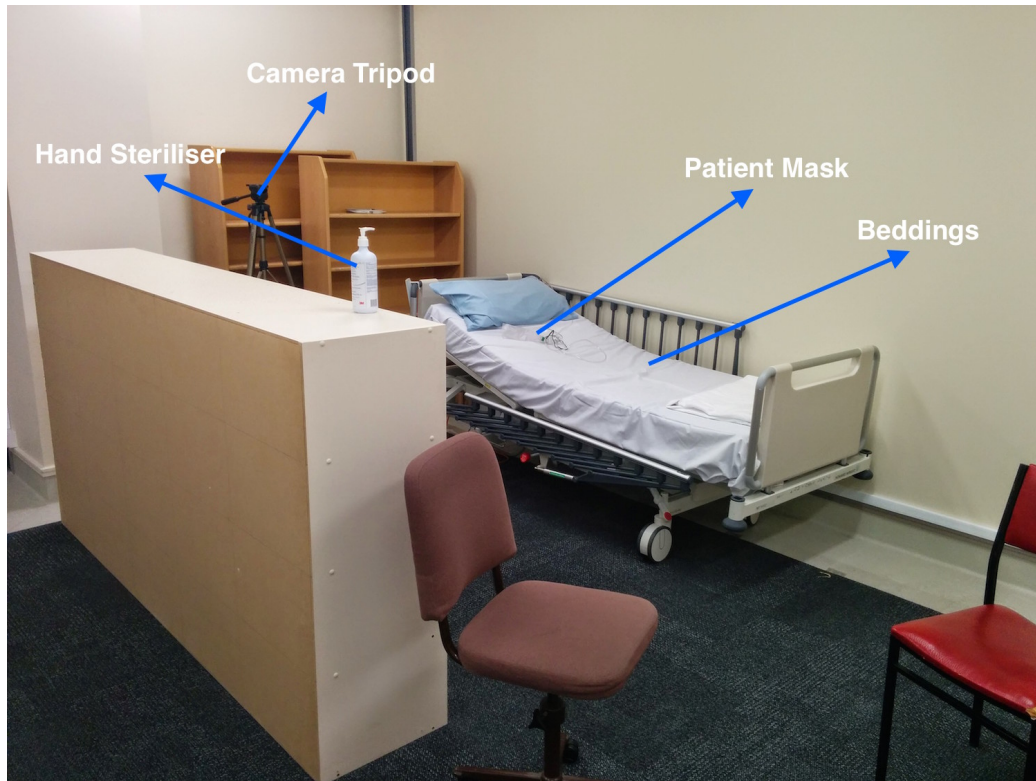


Figure 6.1: Patient Bedside

Three desktop computers were also set aside on a different side of the room, so participants (junior doctor, senior doctor, and patient) could use them to complete questionnaires after completing the trials, as shown in Figure 6.2. An additional computer was also used to show pre-recorded instruction of the experiment and GG tutorial to the clinician at the beginning of the experiment. For further analysis, three video recording devices were used to record each scenario and each interview.



Figure 6.2: Participants answering Questionnaires on Computers

6.4 Experiment Design

Research Hypotheses

Hypotheses 1: There is a statistically significant difference in doctor's focus on patient across the interfaces during patient encounter in a clinical ward rounds.

Hypotheses 2: There is a statistically significant difference in perceived ease of use between the interfaces for accessing patient information during patient encounter in clinical ward rounds.

A within-subject design was used to test the hypotheses, each group of doctor subjects included a junior and a senior doctor working in pairs. The reason for choosing a within-subject design was because of the small number of subjects that were recruited, by using this design we have in effect increased the number of subjects. A junior (house surgeon/junior registrar) and a senior doctor (consultant/senior registrar), each pair completed three different conditions. There were three different patient roles, each patient subject was assigned to one of the groups, the patients were Rebecca Smith, Alan Nicholson and Keith Simpson.

The author used a research randomisation tool ¹, to generate a randomised combination of conditions and patients for each group of subject over the trial

¹www.randomizer.org

period. As an example, for Group 1, the first condition was a paper based interface and the patient was Keith Simpson. For the second condition, a tablet PC interface and the patient was Alan Nicholson, and for the final condition, GG interface and patient was Rebecca Smith. None of the patients was seen by a group of participants more than once and no condition was used more than once by any particular group of doctor subjects. The junior doctors were the ones responsible for retrieving patient information from the source, either paper, or tablet PC. The senior doctors were not using any of the interfaces directly, except during the GG condition.

Additionally, each patient participant was given a script of the role they were going to play, either as Rebecca Smith, Alan Nicholson, or Keith Simpson prior to the experiment, so that they could get familiar with the role and also ensure consistency. No male participant was allowed to play the role of Rebecca Smith, who is a female patient and likewise, no female participant was allowed to play the role of a male patient. This was to prevent confusion for doctors during the trials. The scripts used by the patient participants can be seen in [Appendix G](#)

6.5 Experiment Scenarios

This section describes the different scenarios each group of doctor participants experienced. For the GG and Tablet PC scenario, participants that were playing the role of senior doctors were required to use GG to view the patient information (social history, family history, medications, allergies, etc) during the experiment, with the exception of patient results as they are only presented in the tablet or paper interfaces. Participants that were junior doctors were responsible for taking notes on the tablet PC and pushing patient information from a tablet PC onto the GG when a senior doctor requested for it.

For the tablet PC only scenario, participants that played senior doctors were required to retrieve patient information (social history, family history, medications, allergies, etc) from the tablet either by asking the junior doctor or taking a glance at the content themselves. The junior doctor was also responsible for entering clinical notes using the tablet and looking up information from the application during the experiment.

For the paper-based scenario, participants that were senior doctors were required to retrieve patient information (social history, family history, medications, allergies, etc) using the paper-based clinical notes, an example is shown in Appendix F, either by asking the junior doctor or taking a glance at the documents themselves. The junior doctor was also responsible for taking notes and looking up information from the paper-based clinical notes during the experiment.

6.6 Measurements

The following are the measures that were used to evaluate the different interfaces that were tested.

Following each user test, the participants were asked to fill out questionnaires using Qualtrics online survey software ² about their age, gender, and their experience using the system. The questionnaires given to doctors included a 7-point (Likert scale rating between 0-6) system usability scale (SUS) [9], which is a tool for measuring the usability of systems, another Likert scale (rating between 0-6, strongly disagree to strongly agree) questions to collect their feedback about doctor-patient interaction, and any other comment they may have, as shown in Table 6.1. The patient participants were also asked to fill out a questionnaire about their satisfaction of the visit, as shown in Table 6.2. These questions were also constructed using a 7-point Likert scale (rating between 0-6).

²www.qualtrics.com

Question	Type of Question
I could effectively complete the tasks and scenario using the interface while attending to the patient	7 point Likert Scale
I felt comfortable introducing myself to the patient while using the interface	7 point Likert Scale
I thought having patient information brought up on interface while attending to patient was valuable	7 point Likert Scale
I thought the information presented on the interface was adequate for visit	7 point Likert Scale
I felt use of interface was distracting	7 point Likert Scale
What do you think can be improved?	Text
List other use cases where you think the interface could be applicable	Text
Other comments and suggestions?	Text

Table 6.1: Doctor Questionnaire

Question	Type of Question
The visit was satisfying to me	7 point Likert Scale
I felt uncomfortable with the clinician(s) using the interface	7 point Likert Scale
I felt the leading doctor was distracted from me while using the interface	7 point Likert Scale
The leading doctor listened to me and understood my problems	7 point Likert Scale
Other comments and suggestions?	Text

Table 6.2: Patient Satisfaction Questionnaire

Upon completion of the three tests (3 interfaces), clinicians were asked to fill out an additional questionnaire that collects ranking data about their most and least preferred interface. As an example, the doctor drags the tablet interface to the top of the list as first, tablet-glass second and paper third, and the reasons for his choice, as shown in Table 6.3. Following the ranking questionnaire, each doctor was then interviewed separately for collection of qualitative data using questions listed below.

1. Which of the interfaces was the easiest to use and why?
2. Which of the interfaces was the least distracting at the patient's bedside and why?
3. Which of the interfaces was the most distracting at the patient's bedside and why?
4. What does the junior/senior doctor think about the other senior/junior doctor's ability to focus on patient while using the different interfaces and how does it affect interaction with patient?
5. Have you got any other suggestions or comments?

Question	Type of Question
Rank in order of how satisfying the interfaces were for you	Ranking
Rank in order of how comfortable you felt using the interface	Ranking
Rank in order of the interface you like the most	Ranking
Rank in order of the interface you were the most comfortable with	Ranking

Table 6.3: Interface Ranking Questionnaire

At the end of all trials, all patients were also asked to answer a questionnaire that compares all the interfaces they have experienced over the course of the experiment, as shown in Table 6.4.

Question	Type of Question
Which devices(s) have you had experience with over the course of the trial period (you can select multiple devices)?	Multi-choice
In terms of doctor-patient interaction, which if the interface do you feel was the most distracting to clinicians and why	Single choice and Text
In terms of doctor-patient interaction, which if the interface do you feel was the least distracting to clinicians and why?	Single choice and Text
Which of the interface were you the most comfortable with and why?	Single choice and Text
Any comment, feedback or suggestion?	Text

Table 6.4: Interface Preference Questionnaire for Patients

6.7 Participants

Recruitment of participants was initially done through an advertisement of the experiment on the Canterbury District Health Board CEO’s newsletter as shown in Appendix E, which was targeted at all clinicians in Christchurch hospital. A few weeks before the experiment was scheduled to start, a reminder was sent through email to all clinicians that registered their interest from earlier advertisement. In addition, another email was sent to a number of other clinicians in order to recruit as many participants as possible.

For this experiment, we were fortunate enough to recruit 10 senior doctors (senior medical officers/senior registrars), 2 females and 8 males, age range 25-64 years; 10 junior doctors (house surgeons/junior registrars), 7 females and 3 males, age range 18-34 years; and 5 role-playing actors as patients (medical students and members of the general public), 2 females and 3 males, age range 18-34. In order to be considered for the experiment, all doctor participants had to meet the following criterion: Participants representing junior doctors need to be competent with using tablets or have a basic knowledge of operating smart devices, participants representing senior doctors who will be using GG during the experiment need to have a good sight view so that they

can properly use the GG and all participants must be able to communicate in English.

6.8 Experimental Procedure

For each of the experiment sessions, the author arrived at least 30 minutes prior to the scheduled time the experiment was meant to start. All required documents, such as consent forms and information sheets were printed, recording devices were charged and other devices were setup for the experiment. Pre-recorded introduction to the experiment clip was setup on television to be played to participants before the actual trials start. This was used to guarantee that all participants go through the same training process and receive the same instructions.

Upon arrival, the author greeted the participants, asked them to read the information sheet and to sign the consent form. Then, he introduced the purpose of the study, the role each participant was going to play and the different steps tasks involved. They were then told about the order they were going to do the scenarios, which was pre-defined according to the randomisation method previously explained. The author then reassured participants that only the interface was being tested, not their clinical skills, so they could be calm and relaxed during the experiment. They were also told that they would be video recorded.

Participants were told the aim of each scenario, what information was available and how to obtain it. The doctors were also told they could interact and exchange information freely during the experiment, and they could discuss information prior to seeing the patient, if they thought it is the most efficient way. For the scenario that uses the GG head mounted display, a pre-recorded YouTube™ video ³ of an introduction to GG was played and participants went through a GG training task prior to the experiment, in order to get comfortable with using the device.

For each scenario, three video cameras were constantly recording the doctors, the patients and a bird eye view of the whole bedside. Upon completion of

³www.youtube.com/watch?v=4EvNxWhskf8

each scenario, participants were ushered to different seats to complete questionnaires. Upon completion of the three scenarios, they were then asked to complete an interface ranking questionnaire followed by an interview, which was also recorded. They were then debriefed, thanked and presented with a token of appreciation. Before they leave, they were finally reminded to take the study information sheet with them.

6.9 Pilot Testing

A dummy run of the experiment was carried out prior to starting the trials. This enabled the author to test out the application developed for the HHDs and HMDs. It was also used to test the experiment design including usability questionnaires for determining their suitability (i.e. questions/tasks are too difficult/easy/long/short), and to make appropriate changes if they were not suitable.

The pilot test was done with a registrar acting in the role of a senior clinician using GG, while medical students played the role of junior doctor and patient.

During the pilot testing, some spelling mistakes and grammatical errors were found by the participants both in the software application and the questionnaires. It was also discovered that some medical signs, such as normal blood oxygen level (SpO₂) were misrepresented in the application. A couple of software bugs were also found, for example, irrespective of the patient selected on the tablet, a particular patient information was being pushed to the GG. In addition, some formatting issues were picked up by the participants.

In the questionnaire, the participants suggested that a 'not applicable' option should be added to the Likert scale questions, because some questions were not applicable to them. Another participant pointed out that a hand steriliser should be provided for clinicians to use before and after examining a patient.

All problems listed above were fixed in the prototype application and the questionnaires and suggestions were taken into consideration by the author before the actual experiment started.

Chapter 7

Results and Discussion

From the results drawn in the ward round trials, the author measured the usability of the different interfaces for accessing patient information and their effect on doctor-patient interaction during clinical ward rounds. In general, it was found that two most preferred systems are the tablet PC and the paper-based interface. Subjects felt that these interfaces were more usable and provided the least distraction during doctor-patient interaction.

7.1 Statistical Results

In this section, we show all of the statistical analysis of the results of the experiment, this is used to make claims on the usability of the different systems. Table [7.1](#) shows the demographics of the clinicians that participated in this study. 20 participants (10 sets of Senior and Junior Doctor) completed the three conditions with three patients for each set. All questions in this section are based on a seven point Likert scale (0-6); from strongly disagree to strongly agree.

Table 7.1: Participant Demographics

Role	Characteristic	#(%)
Senior Doctors		
	Male	8(80)
	Female	2(20)
	Age distribution	
	25-34	3(30)
	35-44	6(60)
	44-54	0(0)
	55-64	1(10)
	Used Google Glass before	
	Yes	0(0)
	No	10(100)
	Uses prescription glasses	
	Yes	4(40)
	No	6(60)
	Use of smart devices	
	Daily	10(100)
Junior Doctors		
	Male	3(30)
	Female	7(70)
	Age distribution	
	18-24	1(10)
	25-34	9(90)
	Used Google Glass before	
	Yes	0(0)
	No	10(100)
	Uses prescription glasses	
	Yes	4(40)
	No	6(60)
	Use of smart devices	
	Daily	10(100)
Patients		
	Male	3(60)
	Female	2(40)
	Age distribution	
	18-24	3(60)
	25-34	2(40)

7.1.1 Usability

Are Hand Held and Head Mounted Displays useful for clinicians during clinical ward round?

The author used the System Usability Scale (SUS) [9] for measuring the usability across the different interfaces, since SUS is a reliable tool for measuring the usability. It consists of a 10 item questionnaire and seven response options (0-6) were provided for the participants; from strongly disagree to strongly agree.

In a standard SUS questionnaire, a score above a 68 percentile ranking would be considered above average and anything below 68 is below average. However, the author is not using the five response option and as a result did not use the average scoring option.

To determine if there is a significant difference of perceived usability across the three interfaces, namely tablet PC, paper and HHD+HMD, a set of statistical tests was used as described in the sections below.

Junior Doctors

A Friedman test was run to determine if there were differences in junior doctors perceived ease of use between the three interfaces during clinical ward round, and there was a statistically significant difference $\chi^2(2) = 8.667, p = 0.013$.

Post hoc analysis with the Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) perceived ease of use for the tablet PC, paper-based and HHD+HMD trials were 75.015 (68.347 to 75.1825), 83.35 (61.679 to 94.1855) and 50.8435 (40.8415 to 70.4308), respectively.

There were no statistically significant differences between the tablet PC and paper-based interface trials ($Z = -0.818, p = 0.413$) or between the HHD+HMD and paper-based interface trials ($Z = -2.193, p = 0.028$), despite an overall increase in perceived ease of use in the trials for HHD+HMD. However, there was a statistically significant difference in perceived ease of

use between the HHD+HMD, and the tablet PC interface trial ($Z = -2.666$, $p = 0.008$).

Figure 7.1 shows a visual depiction of the distribution of junior doctors perceived ease of use across the different interfaces.

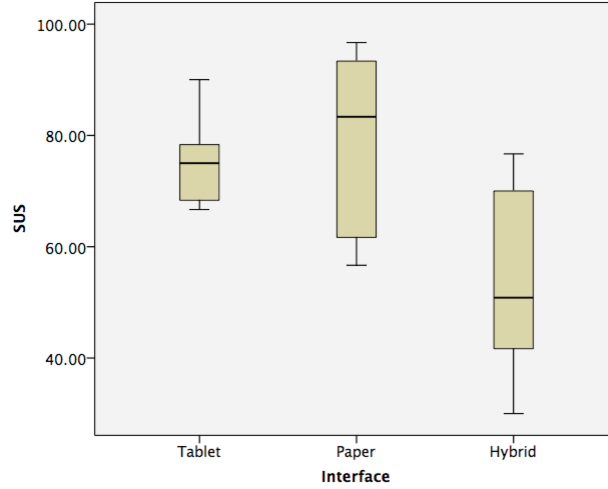


Figure 7.1: Junior Doctors Usability Score of the three different Interfaces

Senior Doctors

A Friedman test was run to determine if there were differences in senior doctors perceived ease of use between the three interfaces during clinical ward round. Perceived ease of use decreased from tablet PC ($Mdn = 75.015$), to paper-based interface ($Mdn = 69.1805$), to HHD+HMD ($Mdn = 41.675$), but the differences were not statistically significant, $\chi^2(2) = 1.168$, $p = .097$.

Figure 7.2 shows a visual depiction of the distribution of senior doctors perceived ease of use across the different interfaces.

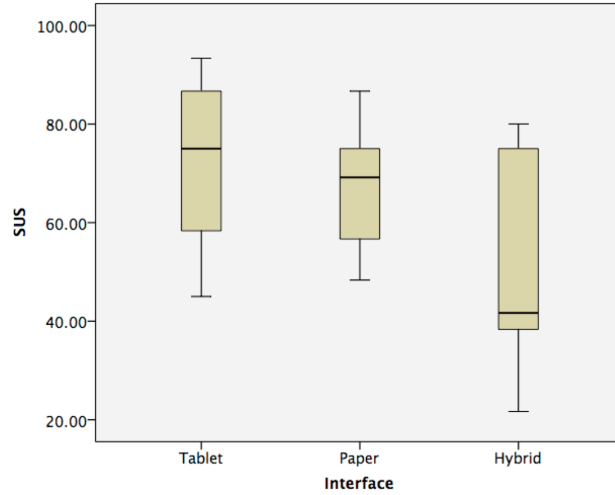


Figure 7.2: Senior Doctors Usability Score of the three different Interfaces

7.1.2 Doctor-Patient Interaction (Doctor Perspective)

Research Question: Is there any difference in the ability to perform tasks at the patient’s bedside across the three different interfaces (paper, hand held display and head mounted display) during CWR?

A Friedman test was run to determine if there were differences in the junior clinician’s ability to effectively perform tasks across the three interfaces during ward round. Median (IQR) perception about the ability to perform task decreased from Paper interface $Mdn = 5.00$ (2.75 to 6.00), to Tablet PC interface $Mdn = 4.50$ (3.75 to 5.00), to HHD+HMD interface $Mdn = 3.50$ (1.75 to 5.00), but the differences were not statistically significant, $\chi^2(2) = 1.687, p = 0.430$.

Figure 7.3 shows a visual depiction of the distribution of junior doctors perceived ability to complete tasks across the different interfaces.

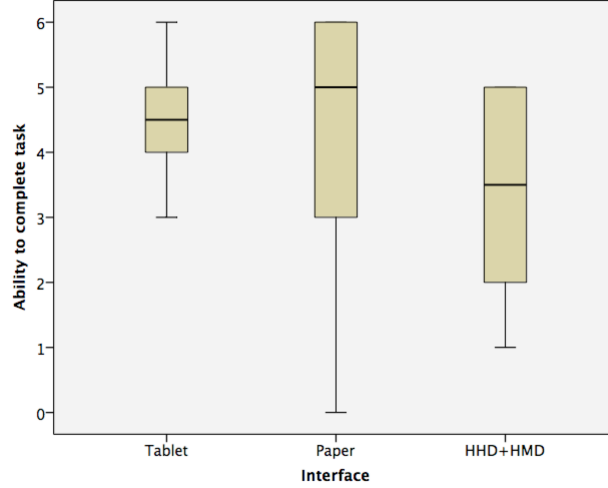


Figure 7.3: Junior Doctors ability to complete tasks across the three Interfaces

However, the Friedman test initially indicated there was a statistically significant difference in senior clinicians perceived ability to effectively perform tasks across the three interfaces during clinical ward round, $\chi^2(2) = 8.667, p = 0.013$. Post hoc analysis with Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) perceived ability to effectively perform tasks using the different interfaces were tablet 5.00 (3.00 to 5.00), paper 5.0 (2.75 to 5.00) and HHD+HMD 2.0 (1.0 to 5.0), respectively. However, there were no significant differences between all the different interfaces, tablet PC and paper interfaces ($Z = -0.828, p = 0.408$), HHD+HMD and paper interfaces ($Z = -1.811, p = 0.070$) or between the HHD+HMD and tablet ($Z = -1.919, p = 0.055$), despite an overall increase in perceived ability to effectively perform tasks during ward round between the HHD+HMD vs tablet PC and paper interfaces. As a result, the differences in perceived ability to complete tasks were not statistically significant. This will be discussed further in section [7.2.1](#).

Figure [7.4](#) shows a visual depiction of the distribution of senior doctors perceived ability to complete tasks across the different interfaces.

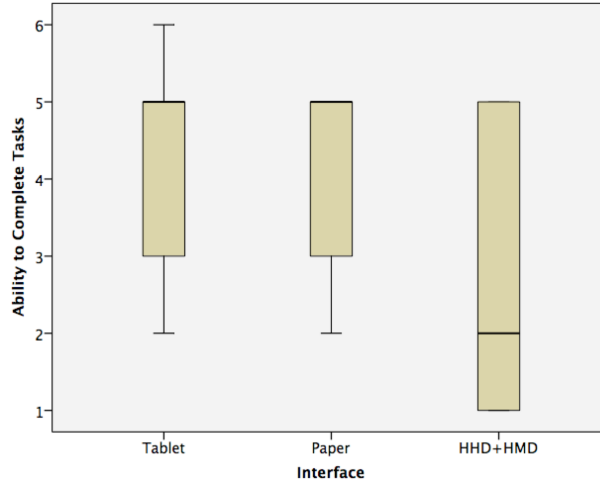


Figure 7.4: Senior Doctors ability to complete tasks across the three Interfaces

Research Question: Is there a difference in how comfortable clinicians felt while interacting with patients across the three different interfaces?

A Friedman test carried out based on Likert scale response to the question, indicated there was a statistically significant difference in junior clinicians ability to comfortably interact with patients across the three interfaces on the patient bedside, $\chi^2(2) = 7.562, p = 0.023$. Post hoc analysis with Wilcoxon signed-rank test was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) perceived ability to comfortably interact with patient using the different interfaces were tablet 4.00 (3.75 to 5.00), paper 5.50 (4.75 to 6.00) and HHD+HMD 3.00 (3.00 to 3.50), respectively. However, there were no significant differences between all the different interfaces, tablet and paper interfaces ($Z = -1.156, p = 0.248$), HHD+HMD and paper interfaces ($Z = -1.615, p = 0.106$) or between the HHD+HMD and tablet ($Z = -1.204, p = 0.229$). As a result, the differences in ability to comfortably interact with patients were not statistically significant. This will be discussed further in section 7.2.1.

For senior clinicians, Friedman test also indicated there was a statistically significant difference in their ability to comfortably interact with patients during ward round across the three different interfaces, $\chi^2(2) = 8.424, p =$

0.015. Post hoc analysis with Wilcoxon signed-rank test were also conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) perceived ability to comfortably interact with patient using the different interfaces were tablet 5.00 (3.75 to 5.25), paper 5.00 (5.00 to 5.00) and HHD+HMD 4.00 (3.50 to 5.00), respectively. There were no significant differences between the tablet PC and paper-based system ($Z = -1.190$, $p = 0.234$) or between the HHD+HMD system and tablet system ($Z = -1.809$, $p = 0.070$), despite an overall increase in perceived ability to comfortably interact with patient in the HHD+HMD vs tablet PC. However, there was a statistically significant difference in perceived ability to comfortably interact with patient between the HHD+HMD system and the paper-based system ($Z = -2.636$, $p = 0.008$).

Which interface was the least distracting for clinicians at the patient's bedside?

Research Question: Which interface is the least distracting and the most distracting for clinicians at the patient's bedside?

A Friedman test was run to determine if there were differences in junior clinicians perceived distraction from patient across the three different interfaces on a patient bedside. The median (IQR) perception of distraction increased from Paper interface $Mdn = 1.00$ (1.00 to 4.50), to Tablet interface $Mdn = 2.00$ (2.00 to 4.25), to HHD+HMD interface $Mdn = 3.00$ (3.00 to 4.00), but the differences were not statistically significant, $\chi^2(2) = 2.108$, $p = 0.349$.

However, for senior clinicians, A Friedman test indicated there was a statistically significant difference in clinicians perceived distraction from patient across the three different interfaces at the patient's bedside during ward round, $\chi^2(2) = 8.914$, $p = 0.012$. Post hoc analysis with Wilcoxon signed-rank test were also conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.017$. Median (IQR) perceived distraction from patient across the different interfaces were tablet 1.00 (1.00 to 1.50), paper 1.50 (1.00 to 2.50) and HHD+HMD 5.00 (3.25 to 5.00), respectively. There were no statistically significant difference between the tablet PC and paper-based system ($Z = -0.426$, $p = 0.670$) or between the HHD+HMD system and tablet system ($Z = -1.958$, $p = 0.050$), despite an overall increase in perceived distraction from tablet to HHD+HMD when attending to patient. However, there was a statistically significant difference in perceived distraction when attending to patient between the HHD+HMD system and

the paper-based system ($Z = -2.514$, $p = 0.012$).

7.1.3 Doctor-Patient Interaction (Patient Perspective)

In addition, patients feedback on clinicians interaction behaviour across the three different interfaces were obtained using a 7-point Likert scale questions. 0 indicating strongly disagree and 6 indicating strongly agree.

Is the doctor's focus on patient affected by the use of different interfaces during patient encounters?

In this section, we describe the patient participants opinion of how clinicians focus on patient were affected by use of different interfaces. Patient participants were asked to answer a set of questions using Likert scale, in the following section we present the results of each of the questions.

This visit was very satisfying to me

A Friedman test was run to determine if there were differences in patients satisfaction across the three different interfaces during ward round. Median (IQR) patient satisfaction increased from tablet system $Mdn = 5.00$ (5.00 to 6.00), to HHD+HMD $Mdn = 5.00$ (5.00 to 6.00), to paper $Mdn = 5.50$ (5.00 to 6.00), but the differences were not statistically significant, $\chi^2(2) = 1.750$, $p = 0.417$.

I felt uncomfortable with him/her using the interface

A Friedman test was run to determine if there were differences in how uncomfortable patients felt across the three different interfaces during ward round. Median (IQR) patient feeling uncomfortable increased from paper system $Mdn = 0.00$ (0.00 to 1.00), to HHD+HMD $Mdn = 0.50$ (0.00 to 1.00), to tablet $Mdn = 0.50$ (-.00 to 1.00), but the differences were not statistically significant, $\chi^2(2) = 1.200$, $p = 0.549$.

I felt the senior doctor was distracted from me while using the interface.

A Friedman test was run to determine patient perception of how distracted the senior clinician were during the ward round across the three different interfaces. Median (IQR) perception increased from tablet system $Mdn = 0.00$ (0.00 to 1.00), to paper $Mdn = 0.00$ (0.00 to 1.25), to HHD+HMD Mdn

= 0.50 (0.00 to 1.00), but the differences were not statistically significant, $\chi^2(2) = 2.333, p = 0.311$.

The senior doctor listened to me and understood my problems.

A Friedman test was run to determine patient opinion of perceived of how attentive and understanding the senior clinician were during the ward round across the three different interfaces. Median (IQR) attentiveness and understanding perception increased from paper system $Mdn = 5.00$ (4.75 to 6.00), to HHD+HMD $Mdn = 5.00$ (5.00 to 6.00), to tablet $Mdn = 5.50$ (4.75 to 6.00), but the differences were not statistically significant, $\chi^2(2) = 0.437, p = 0.804$.

7.2 Qualitative Feedback

In this section, the results collected from junior doctors, senior doctors and patient participants through interviews, questionnaires and general comments are discussed.

Ease of use

When junior doctors were asked which of the systems was the easiest to use, more than half of the junior doctors (6 out of 10 participants), said they preferred paper interface. When asked why, they all said because they were most familiar with the paper based method of accessing patient information during ward round, some added it was easier to draw diagrams and symbols on paper and one doctor said it was easier for him to write than type. The remaining 40 percent all thought the tablet based system was the easiest to use, of which two of them said they use it on a daily basis during ward round.

Another reason they gave was that, more up to date information is readily available on the tablet, whereas on paper sometimes you do not have access to all patient record, because other clinicians have taken them away from the patient folder. To quote two of the junior doctors that preferred using tablet, one said 'tablet is good, because everybody can simultaneously access information and no fighting for clinical notes' and the other, 'I really like the tablet, used it before, it is easier to show the boss info when using tablet'.

The HHD+HMD system was not preferred by any junior doctor, this could

be because the junior doctors did not use the Google Glass throughout the experiment. Also based on the feedback received from junior doctors, it could also be said that junior doctors preferred the devices they were more familiar with using. Interestingly though, most of the doctors (4 out of 6) that preferred paper based method still indicated an interest in the tablet PC and Google Glass, they said with more practice and training with the devices, they believe they will get full benefit from them.

More than half of the senior doctors preferred the tablet PC in terms of usability (6 out of 10 participants). The reasons they gave are; it was easier and quicker to find patient information with it, more information such as results were accessible at the patient's bedside and as a result more decision can be made on the bedside, it allowed data input, it has a good balance between access to information and not getting distracted from patient, its interface was simple, clean, and layout was very clear.

Almost all doctors (9 out of 10 participants) said the HHD+HMD system was the most difficult to use mainly due to GG (HMD). The reasons being; GG was distracting from engaging with patient, limited information can be viewed, it can be difficult to adjust GG when using prescription glasses. It should be said, however, that most of the senior doctors said with more experience, it could get easier. To quote two of the senior doctors, one said 'It's just like when you get an iPhone the first time, you have to spend a couple of hours with your kids before you become more competent'. Another senior doctor said, 'Surprised how easy it was to use Glass after a tutorial'. There were also several other positive comments about it; some doctors said it was fun and they like the cool factor of Glass, the chronology of information displayed on it. It is possible that after more training and familiarity with the GG, they will find it easier to use. However, this is something that requires more research.

The remaining 40 percent of senior doctors thought the paper based method was the easiest to use and gave the following reasons; comfort of familiarity, information is in chronological order, easier to flick through and scan patient information on the the paper. However, it also has its own disadvantages, which are, the need to turn attention away from patient to flick through pages, accuracy of data, readability when notes are taken by someone else, transfer of data for accessibility elsewhere can be challenging and when the notes are incomplete, which could make it illegible.

Distraction from patient

Most doctors, both junior and senior (16 out of 20), said the tablet PC and paper were the least distracting on the patient bedside. This could most likely be explained by the fact that, the junior doctors were the ones using the tablets/clinical notes during the ward round and were not directly interacting with the patient, while the senior doctors were always the ones interacting with and examining patients and they do not have any document or device on their hands to look at. Whereas, during the HHD and HMD scenarios, the senior doctor often get information pushed on to the Google Glass, hence, the need to gaze at the screen during patient encounter and this could be perceived as distraction from patient.

The given reasons about why the combination of HHD and HMD was the most distracting were;

- The GG interface affects interaction between doctor-patient.
- The need to pause when there is a notification.
- Patient cannot see what the senior doctor is looking at.
- Weird feeling when navigating using the touchpad of the GG in front of patient.
- Difficulty navigating through it.
- It causes loss of focus on patient.

However, three junior doctors said that the combined use of HHD and HMD system was the least distracting, because there was no need to deal with big folders and conversation is more natural.

Furthermore, one of the junior doctors said the paper-based method was distracting as well, because it can be difficult and time consuming to flick through files in the clinical notes folder during consultation at the patient's bedside and in situations where files are missing, the consultation often gets paused until the document is found.

Feedback on interaction between Senior doctor and patient

Junior doctors were asked to give a subjective feedback about their thought on the interaction between the senior doctor and patient across the three

different methods. Most (8 out of 10) said they felt paper and tablet PC interfaces were not distracting to patients. The following is a summary of reasons given; for the tablet interface, there is no need to leave the patient side in order to get patient result as the result was readily available on the tablet PC, as a consequence, the interaction was not paused. Another reason given was that, the junior doctors read information out for the senior doctors on request, as a result, the need for the senior doctor to put focus on the tablet or paper is sometimes eliminated.

However, for the HHD+HMD interface, most junior doctors said, it was a bit distracting, mostly because the senior doctor spends time trying to interact with the Google Glass, as a result the consultation gets slowed down in comparison with other methods.

Feedback on getting junior doctor to retrieve information from interfaces

When senior doctors were asked their thoughts on the junior doctors ability to retrieve information from different interfaces, the senior doctors were generally approving. They said that the junior doctors were quick at finding information, interactive and were good at anticipating what information the senior doctors needed during consultation.

Patients feedback

Similar to previous work [3], most patients gave a high satisfaction rating for the interaction between them and the senior doctor across all the three different interfaces. When asked to give further comments, the patients feedback were as follows; For the paper based method, they felt it was a more natural consult and the senior doctor was not distracted, the senior doctor was mostly talking to them during the consult. On the negative feedback for the paper, one patient said they felt there wasn't enough information immediately available on the paper notes.

Feedback on the combined HHD and HMD method can be summarised as follows; one patient said he forgot the senior doctor was wearing the GG, others said that they did not notice the senior doctor using the device. However, on the contrary, one of the patients said that there was a moment when she felt the senior doctor was having difficulty using the GG, and had to ask the junior doctor to read out the information from the tablet PC instead. Although, she said she did not feel the senior doctor was distracted.

The tablet method also received similar comments as the other methods. Some of the patients said, they felt the senior doctor was mostly talking to them and was mostly focused on them during the consultation.

The patients gave a high rating to doctors during visits, so it could be an indication that different methods of interaction could be used during ward round consultations, without affecting the interaction between the doctors and their patients. Additionally, it could be an indication that patients have trust in their doctors and believe they are using the devices for the patient's benefit and could also be because of the limited sample size of patients during the experiment. However, these are topics that are open to further research.

7.2.1 Discussion

Doctor-patient interaction is central to every doctor's practice. Clinicians have been concerned that the introduction of electronic devices could have a negative effect on interaction between them and patients. In this study, the author designed an electronic health record interface on HHD and a HMD, so clinicians could access patient information during ward round. The study focused on the usability of the HHD and HMD interfaces in comparison with the existing paper-based interface, and their effect on doctor-patient interaction during clinical ward rounds.

In terms of usability, despite significant improvements in HMDs hardware and software since Liu et al. 2009 study on use of HMDs in operating room [39], results show that clinicians were able to achieve their objectives across the three interfaces, but there was a perceived difference in the usability of the devices. Friedman test and post hoc analysis with Wilcoxon signed-rank test showed that there were no statistically significant difference in junior doctors perceived ease of use between the tablet PC and paper-based interfaces or between HHD+HMD and paper-based interface. However, there was a difference between the HHD+HMD and tablet, this could be because junior doctors were responsible for pushing information to the HMD interface during ward and felt that they did not know if the senior doctor was receiving the information on the GG. Another reason could be that, even though the junior doctors did not use the GG during the CWR, seeing how some senior doctors were struggling with using the device, could give them a negative perception of easy of use.

However, for the senior doctors' perceived ease of use, a similar test showed that there was no statistically significant difference across all the interfaces. The fact that there wasn't a statistically significant difference in senior doctor's perceived ease of use across the interfaces could be an indication that the GG may not be that bad. In addition, there is a high variance in perceived ability to perform tasks using the GG across the clinicians. Given that GG has never been used by any of the participants and they've all had experience using tablet PCs or smart phones, the response from clinicians is relatively good. The author believes that the result of the study might have also been affected by time limitation for clinicians to become familiar with learning how to use the GG device, given they've never used it prior to the experiment. Increased level of training on how to use the device could improve the usability and overall satisfaction.

In terms of doctor-patient interaction, the patients all had a high satisfaction rating across the three different interfaces, this finding is comparable to earlier research that showed the patients are less concerned about the devices the clinicians are using and most patients believe that clinicians are using the devices so they could provide better care for them [3].

In terms of social acceptance of the devices, the HHD had a better acceptance rate than the HMD, likely because of their familiarity with it, as they all use smartphone/tablets daily. The author believes that the acceptance rate of HMDs will increase in the near future. This is because, clinicians currently use a wide range of medical devices to perform their duties, and to help them take care of patients, ranging from stethoscopes to heart rate monitor. Devices like the vital signs monitoring HMD shown in Figure 7.5, which includes a wireless microphone, a battery in the backpack are currently being used by clinicians. Although, these devices play an important role in patient care as the clinicians that use it, a lot of them are bulky, immobile and hard to use. GG has the advantage of being portable, technologically advanced, and potentially more useful than a lot of them. As a result, the author believes that as clinicians get more familiar with using HMD devices like GG and seeing the potential benefits of helping them perform their duties, they will be more inclined to adopt them. However, a much larger sample will be required in future studies to further investigate this.



Figure 7.5: Vital signs monitoring HMD, sourced from [39]

Overall, the HHD and the paper-based interfaces were on a par with each other, while the HMD interface (Google Glass) was not well accepted by the clinicians because of unfamiliarity with using the device, its distraction from engaging with patient, its limited screen size, and difficult to use for people wearing prescription glasses, et cetera. Doctors are very conservative, one of the participants in this study was quoted to have said, "In the medical world, there is a momentum against change, against trying new stuff before it is proven to be a benefit, having such experiments as yours, is a good way to get clinicians to try stuff." The author believes that as wearable HMD devices, such as Google Glass become more widely adopted in the society, the adoption rate of the devices in healthcare will rapidly increase. Perhaps, sometimes not having any interface is the best interface.

On the positive side, users felt that GG has lots of potential in other areas of medicine, such as surgery, tele-medicine, trauma procedure and teaching/training. Patient participants did not feel it was distracting the doctor during consultation. In addition, most participants were impressed with its capability and said they believe with enough training, it will be more useful.

Other Ideas

Senior and junior doctors also gave some ideas on things they think can be improved or added to improve their current work process during ward round. They commented on the need to have a way of seeing what the senior doctor was currently looking at on the GG. This will help junior doctors collaborate better with their senior counterparts. They also commented that having a stylus will be handy when using the tablet PC. It will allow those that prefer writing to still be able to do so and it will also allow drawing of diagrams and symbols. Another comment, was that the speed of pushing information to the GG from the tablet should be faster. Also, the use of voice commands as a way of interacting with GG was recommended by many doctors. They remarked that it will be faster to bring up information rather than asking a junior doctor who is busy writing notes. Participants also thought that it would be good to have an anticipatory kind of system, that detects the type of information that will be needed by the doctor and automatically brings the information up.

A lot of the doctors gave other ideas that were not related to the experiment, but that could help improve to their work processes in general, such as the following;

1. A notification system with a counter that indicates when new information is available on a patient record.
2. A real time observation on GG so that a clinician wearing the HMD can observe information and get alerts about their patients in real time.
3. The person leading resuscitation could use GG to coordinate things.
4. A remote rural practitioner could communicate, convey patients images, live stream with another consultant remotely while still having the ability to focus on patient using GG.
5. GG could be used for teleconferencing.
6. Decision support.
7. For recording surgery for training purpose.

Furthermore, one of the doctors suggested that all the three different interfaces should be combined and used during ward round, to compliment each other.

From the developers point of view, some of the reasons why the GG and

the HMD+HHD was not well accepted by clinicians are as follows; the Wi-Fi on Glass was not as reliable as it should be, as a result, there is often notification lagging, which led some clinicians to ask for information directly instead of waiting to get it from GG. Using different technologies such as Bluetooth, personal area networks, et cetera. could increase the speed and network reliability. In addition, developers have little control over how users interact with GG. The clinicians had difficulty using the device's touchpad, but the author believes that as similar devices as GG become more widely available in the society, people will get more familiar with how to interact with them and in return clinicians may also find it easier to interact with them.

The author will also like to make some recommendations for future developers who are building similar interfaces for use in medical settings. Communication between devices should be encrypted, as it not not advisable to send any patient information using an open and insecure network. Information should be presented in a clearly structured way in both the HHD and the HMD interfaces. In addition, hands-free operation should be allowed for using the interface, as hygiene is an issue that clinicians take seriously. Finally, when developing new interfaces, developers should ensure that their new interface improves the existing processes. Sometimes, having no interface is the best interface.

7.3 Threats to Validity

Participants new to using Glass

All the participants had little or no experience with using the GG. Although, all doctors went through the same training tasks on how to use GG, and they all said they were confident enough to use it before the tests, a lot of the doctors struggled to use the device during experiments. However, it must be said that there were some doctors that picked up how to use it quickly and did very well during the ward round. It would have been much better if all participants spent a longer time training and getting familiar with the device before the experiment, but unfortunately, given the limited busy schedule of doctors and limited number of GGs, it was not an option in the study.

Patient participants in more than one experiment

When conducting the tests, due to cost of limitation of resources, some of the patient participants went through more than one set of doctors. In other words, they had experience with multiple doctors on different days. However, for every set of doctors, each patient participant was assigned to only one condition. Ideally, for each trial a real patient rather than actors would be used to get feedback.

7.4 Unanswered Questions

This section discusses the question that was not answered in this research, but would be interesting to investigate further.

Was there a difference in time to reach diagnosis across the three Interface conditions?

It would be valuable to compare the how long it took senior doctors to diagnose patients across the different interfaces, this will indicate whether there is a significant difference in reaching diagnosis between the HDS, tablet PC and paper based method of accessing patient information. In this study, the author did not carry out the video analysis due to time constraints.

7.5 Results Summary

It was hoped that the introduction of HHDs and HMDs into the CWR process would help improve the process, as both devices satisfy the requirements gathered earlier. They are portable, support web applications, mobile, unobtrusive, and support input. Additionally, GG is hands free, and a tablet PC could be used to share content with patient. The two most preferred methods are the tablet PC and the paper-based interface for perceived usability and least distraction during doctor-patient interaction. This is because, when using these interfaces, senior doctors were able to fully focus on patients without the need to retrieve information from any of the interfaces themselves. While the junior doctors were mainly focused on retrieving information upon re-

quest by the senior doctor and not on interaction with the patient. Using this approach, interfaces supported good collaboration between the clinicians.

The clinicians had concerns about the use of GG during CWR, its perceived negative effect on doctor-patient interaction and technical issues. The reasons given were; the CWR gets slowed down because the senior doctors spend a lot of time trying to use the GG on patient bedside. Patients do not have an idea of what the senior doctor is looking at on the GG, and some clinicians felt uncomfortable while using the touchpad in front of the patient. It causes loss of focus on the patient. However, for the HMD (GG), patients had a positive satisfaction with the interface and didn't think it was distracting the clinicians.

Clinicians also gave recommendations on how they think the HHD+HMD interface could be improved, such as using voice commands on the GG as input rather than the touchpad, having an anticipatory system on the GG interface that brings information up automatically. On the HHD, the ability to see what a senior doctor is currently looking at on the GG, and ability to use stylus as an input device on the tablet PC

Before it can be recommended for use in CWR by clinicians, improvements to the hardware and software of the HMD are required.

Chapter 8

Conclusion and Future Work

8.1 Conclusion

To the best of the author's knowledge, this study was the first to compare the three different interfaces tested during clinical ward round process.

The author came to the conclusion that for a system to successfully be adopted in clinical ward round, three components needed to be taken into account: the interface/technology, the software (interface, functionality), and the user (both patient and clinicians). Failure to take all the three components into consideration when designing systems for use in clinical ward round could prevent it from being used by clinicians.

8.2 Contribution

The contributions of this study are the following; the general research questions presented in Chapter 4 were answered. Functional prototype interfaces were developed for a HMD and a HHD and tested during consultations in experiment's CWR scenarios. The four basic activities of interaction design (needs analysis, developing alternative designs, building interactive version of the design and evaluating the design) were iteratively used for building the prototype.

An evaluation of the prototype, which included a formal user study, a comparison of usability and doctor-patient interaction across three different methods of accessing patient information during a CWR session, namely; paper based, tablet PC based, and HHD+HMD interface. Subjective feedback was collected from senior, junior doctors and patients about usability, distractions and their general experience with the prototype and their comments on how current work process can be improved using the technologies. Finally, a written and presented report was completed on the research and its findings.

8.3 Future Research

This study was based on a small sample size. A future study should be done with a larger sample size of junior doctors, senior doctors and patients. In addition future research should test the interfaces with real patients in a real clinical setting.

A further investigation will be needed to measure the effect of using voice commands to interact with GG during ward round, how it affects usability and interaction between doctor and patient.

It would be worth extending the prototypes based on the findings of this research, such as having a richer set of information manipulation methods on the devices, the ability to annotate on devices among many others.

An extended trial to test the hypothesis that with more practice and familiarity with GG doctors will find it easier to use and enjoy using it more.

A further investigation will also be required to understand why patient satisfaction was high irrespective of the technology or devices doctors used during the clinical ward round.

Another interesting research path, would be to investigate the influence of doctors communicative behaviours, such as body movement, non-verbal communication (body language, eye-gaze) from frustration or failure of software systems during ward round has on patients.

Future research should also try different types of interface design and user interaction. And it should investigate how other networking technologies could be used to address network lagging issues.

In future work, further investigation measuring task performance time and video analysis to examine verbal and non-verbal behaviour should also be conducted.

Lastly, future research should investigate the use of other types of HMD devices and also redesign the HMD interface to make it more usable, based on the feedback collected during this experiment.

Bibliography

- [1] Kurt Adamer et al. “Developing a Wearable Assistant for Hospital Ward Rounds: An Experience Report”. In: *Proceedings of the 1st International Conference on The Internet of Things*. IOT’08. Zurich, Switzerland: Springer-Verlag, 2008, pp. 289–307. ISBN: 3-540-78730-5, 978-3-540-78730-3. URL: <http://dl.acm.org/citation.cfm?id=1793060.1793084>.
- [2] Urs-Vito Albrecht et al. “Google Glass for documentation of medical findings: evaluation in forensic medicine”. In: *Journal of medical Internet research* 16.2 (2014).
- [3] Onur Asan and Enid Montague. “Physician interactions with electronic health records in primary care”. In: *Health Systems* 1.2 (2012), pp. 96–103.
- [4] H. Benko, E.W. Ishak, and S. Feiner. “Collaborative mixed reality visualization of an archaeological excavation”. In: *Mixed and Augmented Reality, 2004. ISMAR 2004. Third IEEE and ACM International Symposium on*. Nov. 2004, pp. 132–140. DOI: [10.1109/ISMAR.2004.23](https://doi.org/10.1109/ISMAR.2004.23).
- [5] JHM Bergmann and AH McGregor. “Body-worn sensor design: what do patients and clinicians want?” In: *Annals of biomedical engineering* 39.9 (2011), pp. 2299–2312.
- [6] Timo Bleeker, Gun Lee, and Mark Billinghurst. “Ego-and Exocentric interaction for mobile AR conferencing”. In: *Mixed and Augmented Reality (ISMAR), 2013 IEEE International Symposium on*. IEEE. 2013, pp. 1–6.

- [7] Nick Booth, Paul Robinson, and Judy Kohannejad. “Identification of high-quality consultation practice in primary care: the effects of computer use on doctor–patient rapport”. In: *Informatics in primary care* 12.2 (2004), pp. 75–83.
- [8] Tom Brekka. “Select mobile computers tailored to healthcare environment.” In: *Health management technology* 16.13 (1995), pp. 48–50.
- [9] John Brooke. “SUS-A quick and dirty usability scale”. In: *Usability evaluation in industry* 189.194 (1996), pp. 4–7.
- [10] Rahul Budhiraja, Gun A Lee, and Mark Billingham. “Using a HHD with a HMD for Mobile AR Interaction”. In: *Mixed and Augmented Reality (ISMAR), 2013 IEEE International Symposium on*. IEEE. 2013, pp. 1–6.
- [11] Victoria Carlsson et al. “Wearable computers in clinical ward rounds”. In: *Applied Wearable Computing (IFAWC), 2006 3rd International Forum on*. VDE. 2006, pp. 1–9.
- [12] Peter R Chai et al. “The Virtual Toxicology Service: Wearable Head-Mounted Devices for Medical Toxicology”. In: *Journal of Medical Toxicology* 10.4 (2014), pp. 382–387.
- [13] Jingyuan Cheng et al. “A Wearable, Conductive Textile Based User Interface for Hospital Ward Rounds Document Access”. In: *Smart Sensing and Context*. Springer, 2008, pp. 182–191.
- [14] Andrea Colaço et al. “Mime: compact, low power 3d gesture sensing for interaction with head mounted displays”. In: *Proceedings of the 26th annual ACM symposium on User interface software and technology*. ACM. 2013, pp. 227–236.
- [15] Alicia Cowan. *Social Media giants – why they use blue as their primary branding colour*. URL: <http://www.aliciacowan.com/social-media-and-digital-marketing/strategy-and-advice/social-media-giants-branding>.
- [16] Dan F Criswell and Michael L Parchman. “Handheld computer use in US family practice residency programs”. In: *Journal of the American Medical Informatics Association* 9.1 (2002), pp. 80–86.
- [17] Joseph L Dvorak. *Moving Wearables Into the Mainstream: Taming the Borg*. Springer Science & Business Media, 2007.

- [18] Steven Feiner and Ari Shamash. “Hybrid User Interfaces: Breeding Virtually Bigger Interfaces for Physically Smaller Computers”. In: *Proceedings of the 4th Annual ACM Symposium on User Interface Software and Technology*. UIST ’91. Hilton Head, South Carolina, USA: ACM, 1991, pp. 9–17. ISBN: 0-89791-451-1. DOI: [10.1145/120782.120783](https://doi.org/10.1145/120782.120783). URL: <http://doi.acm.org/10.1145/120782.120783>.
- [19] S. Feiner et al. “A touring machine: prototyping 3D mobile augmented reality systems for exploring the urban environment”. In: *Wearable Computers, 1997. Digest of Papers., First International Symposium on*. Oct. 1997, pp. 74–81. DOI: [10.1109/ISWC.1997.629922](https://doi.org/10.1109/ISWC.1997.629922).
- [20] Roy Fielding. “Representational state transfer”. In: *Architectural Styles and the Design of Network-based Software Architecture* (2000), pp. 76–85.
- [21] Gyeong-Nam Gimhae. “Six human factors to acceptability of wearable computers”. In: (2013).
- [22] *Glass Design Style*. <https://developers.google.com/glass/design/style>. Accessed: 2015-03-11.
- [23] Michael A Grasso, M Jim Yen, and Matthew L Mintz. “Survey of hand-held computing among medical students”. In: *Computer methods and programs in biomedicine* 82.3 (2006), pp. 196–202.
- [24] Neset Hikmet and Shaw K Chen. “An investigation into low mail survey response rates of information technology users in health care organizations”. In: *International journal of medical informatics* 72.1 (2003), pp. 29–34.
- [25] Andreas Holzinger and Maximilian Errath. “Mobile computer Web-application design in medicine: some research based guidelines”. In: *Universal Access in the Information Society* 6.1 (2007), pp. 31–41.
- [26] Andreas Holzinger et al. “Typical problems with developing mobile applications for health care”. In: *ICE-B 2008* (2008), p. 235.
- [27] John Hsu et al. “Health information technology and physician-patient interactions: impact of computers on communication during outpatient primary care visits”. In: *Journal of the American Medical Informatics Association* 12.4 (2005), pp. 474–480.

- [28] Adrian Ilie et al. “Combining Head-mounted and Projector-based Displays for Surgical Training”. In: *Presence: Teleoper. Virtual Environ.* 13.2 (Apr. 2004), pp. 128–145. ISSN: 1054-7460. DOI: [10.1162/1054746041382375](https://doi.org/10.1162/1054746041382375). URL: <http://dx.doi.org/10.1162/1054746041382375>.
- [29] Barry Kollee, Sven Kratz, and Anthony Dunnigan. “Exploring gestural interaction in smart spaces using head mounted devices with ego-centric sensing”. In: *Proceedings of the 2nd ACM symposium on Spatial user interaction*. ACM. 2014, pp. 40–49.
- [30] P. Kotzé et al. *Creativity and HCI: From Experience to Design in Education: Selected Contributions from HCIED 2007, March 29-30, 2007, Aveiro, Portugal*. IFIP Advances in Information and Communication Technology. Springer, 2008. ISBN: 9780387890210. URL: <https://books.google.co.nz/books?id=XQ2RNze8B6oC>.
- [31] Stas Krupenia and Penelope M Sanderson. “Does a Head-Mounted Display Worsen Inattentive Blindness?” In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 50.16 (2006), pp. 1638–1642. DOI: [10.1177/154193120605001626](https://doi.org/10.1177/154193120605001626). eprint: <http://pro.sagepub.com/content/50/16/1638.full.pdf+html>. URL: <http://pro.sagepub.com/content/50/16/1638.abstract>.
- [32] Avraham Leff and James T Rayfield. “Web-application development using the model/view/controller design pattern”. In: *Enterprise Distributed Object Computing Conference, 2001. EDOC’01. Proceedings. Fifth IEEE International*. IEEE. 2001, pp. 118–127.
- [33] James D Legler and Randall Oates. “Patients’ reactions to physician use of a computerized medical record system during clinical encounters.” In: *The Journal of family practice* (1993).
- [34] Sarah Lelievre and Karen Schultz. “Does computer use in patient-physician encounters influence patient satisfaction?” In: *Canadian Family Physician* 56.1 (2010), e6–e12.
- [35] Jan Leupold and Stephan Behrendt. “The hybrid display: Smooth transition between virtual and real views for location unbound observations in telepresence applications”. In: *Joint International COE/HAM-SFB453 Workshop on Human Adaptive Mechatronics and High Fidelity Telepresence*. 2005, pp. 25–30.

- [36] Maya Levin-Sagi et al. “A Comprehensive Human Factors Analysis of Wearable Computers Supporting a Hospital Ward Round”. In: *Applied Wearable Computing (IFAWC), 2007 4th International Forum on*. VDE. 2007, pp. 1–12.
- [37] Herbert S Lin, Willam W Stead, et al. *Computational Technology for Effective Health Care:: Immediate Steps and Strategic Directions*. National Academies Press, 2009.
- [38] Michael Linhoff. “Mobile computing in medical and healthcare industry.” In: *Mobile Computing in Medicine*. 2002, pp. 217–225.
- [39] D. Liu, S.A. Jenkins, and P.M. Sanderson. “Clinical Implementation of a Head-Mounted Display of Patient Vital Signs”. In: *Wearable Computers, 2009. ISWC '09. International Symposium on*. Sept. 2009, pp. 47–54. DOI: [10.1109/ISWC.2009.36](https://doi.org/10.1109/ISWC.2009.36).
- [40] David Liu, Simon A Jenkins, and Penelope M Sanderson. “Patient monitoring with head-mounted displays”. In: *Current Opinion in Anesthesiology* 22.6 (2009), pp. 796–803.
- [41] David Liu et al. “Monitoring with head-mounted displays: performance and safety in a full-scale simulator and part-task trainer”. In: *Anesthesia & Analgesia* 109.4 (2009), pp. 1135–1146.
- [42] Yen-Chiao Lu et al. “A review and a framework of handheld computer adoption in healthcare”. In: *International journal of medical informatics* 74.5 (2005), pp. 409–422.
- [43] Paul Lukowicz et al. “WearIT@work: Toward Real-World Industrial Wearable Computing”. In: *IEEE Pervasive Computing* 6.4 (2007), pp. 8–13. ISSN: 1536-1268. DOI: <http://doi.ieeecomputersociety.org/10.1109/MPRV.2007.89>.
- [44] Rísín McNaney et al. “Exploring the acceptability of google glass as an everyday assistive device for people with parkinson’s”. In: *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*. ACM. 2014, pp. 2551–2554.
- [45] microvisiontracker. *Microvision Nomad*. [Online; accessed June 18, 2014]. 2009. URL: <http://microvisiontracker.blogspot.co.nz/2011/10/microvision-nomad.html>.

- [46] Enid Montague et al. “Modeling eye gaze patterns in clinician–patient interaction with lag sequential analysis”. In: *Human Factors: The Journal of the Human Factors and Ergonomics Society* 53.5 (2011), pp. 502–516.
- [47] Calkin S Montero et al. “Would you do that?: understanding social acceptance of gestural interfaces”. In: *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services*. ACM. 2010, pp. 275–278.
- [48] Cecily Morrison et al. “Electronic patient record use during ward rounds: a qualitative study of interaction between medical staff”. In: *Critical Care* 12.6 (2008), R148.
- [49] Oliver J Muensterer et al. “Google glass in pediatric surgery: An exploratory study”. In: *International Journal of Surgery* 12.4 (2014), pp. 281–289.
- [50] H Noma et al. “Wearable sensors for auto-event-recording on medical nursing-user study of ergonomic design. Wearable Computers, 2004. ISWC 2004”. In: *Eighth International Symposium on*. Vol. 1. 2004.
- [51] James A O’Hare. “Anatomy of the ward round”. In: *European journal of internal medicine* 19.5 (2008), pp. 309–313.
- [52] L.M.L. Ong et al. “Doctor-patient communication: A review of the literature”. In: *Social Science and Medicine* 40.7 (1995), pp. 903–918. ISSN: 0277-9536. DOI: [http://dx.doi.org/10.1016/0277-9536\(94\)00155-M](http://dx.doi.org/10.1016/0277-9536(94)00155-M). URL: <http://www.sciencedirect.com/science/article/pii/027795369400155M>.
- [53] A Ant Ozok et al. “A comparative study between tablet and laptop PCs: User satisfaction and preferences”. In: *Intl. Journal of human–computer interaction* 24.3 (2008), pp. 329–352.
- [54] PDA Cortex. *Microvision Ships First Nomad Personal Display Systems*. [Online; accessed July 25, 2014]. 2002. URL: http://www.pdacortex.com/microvision_nomad.htm.
- [55] Riskheads.org. *Wearable Technology To Date*. 2009. URL: <http://www.riskheads.org/wearable-technology-lead-insurance-premium-parity> (visited on 01/30/2015).

- [56] Debra L. Roter et al. “The Expression of Emotion Through Nonverbal Behavior in Medical Visits”. In: *Journal of General Internal Medicine* 21.S1 (2006), S28–S34. ISSN: 1525-1497. DOI: [10.1111/j.1525-1497.2006.00306.x](https://doi.org/10.1111/j.1525-1497.2006.00306.x). URL: <http://dx.doi.org/10.1111/j.1525-1497.2006.00306.x>.
- [57] samsung.com. *Google Glass*. URL: <http://www.samsung.com/global/business/mobile/product/galaxy-tab/GT-P5200GNASEE> (visited on 02/25/2015).
- [58] Joseph Sclafani, Timothy F Tirrell, and Orrin I Franko. “Mobile tablet use among academic physicians and trainees”. In: *Journal of medical systems* 37.1 (2013), pp. 1–6.
- [59] Aviv Shachak and Shmuel Reis. “The impact of electronic medical records on patient–doctor communication during consultation: a narrative literature review”. In: *Journal of evaluation in clinical practice* 15.4 (2009), pp. 641–649.
- [60] Gil L Solomon and Mark Dechter. “Are patients pleased with computer use in the examination room?” In: *The Journal of family practice* (1995).
- [61] Rebecca J Spencer et al. “The use of Google Glass for airway assessment and management”. In: *Pediatric Anesthesia* 24.9 (2014), pp. 1009–1011.
- [62] Scott M Strayer et al. “Patient attitudes toward physician use of tablet computers in the exam room”. In: *Family medicine* 42.9 (2010), p. 643.
- [63] Geoffrey W Stuart, Ken I McAnally, and James W Meehan. “Head-up displays and visual attention: Integrating data and theory”. In: *Human factors and aerospace safety* 1.2 (2001).
- [64] Frank Sullivan and Elizabeth Mitchell. “Has general practitioner computing made a difference to patient care? A systematic review of published reports”. In: *Bmj* 311.7009 (1995), pp. 848–852.
- [65] Garry Tan et al. “Effects of voice vs. remote on US and Japanese user satisfaction with interactive HDTV systems”. In: *CHI’03 Extended Abstracts on Human Factors in Computing Systems*. ACM. 2003, pp. 714–715.
- [66] *User-centered design*. <https://bootstrapmaster.com/category/tutorials/>. Accessed: 2015-03-15.

- [67] S Vallurupalli et al. “Wearable technology to improve education and patient outcomes in a cardiology fellowship program-a feasibility study”. In: *Health and Technology* 3.4 (2013), pp. 267–270.
- [68] David K Vawdrey et al. “A tablet computer application for patients to participate in their hospital care”. In: *AMIA Annual Symposium Proceedings*. Vol. 2011. American Medical Informatics Association. 2011, p. 1428.
- [69] Chris Weller. *Google Glass Saves Man’s Life Thanks To Doctor’s Quick Access To Patient File*. Apr. 2014. URL: <http://www.medicaldaily.com/google-glass-saves-mans-life-thanks-doctors-quick-access-patient-file-275802> (visited on 06/17/2014).
- [70] Peter Weller et al. “Evaluation of a wearable computer system for telemonitoring in a critical environment”. In: *Personal and Ubiquitous Computing* 14.1 (2010), pp. 73–81.
- [71] Amina White and Marion Danis. “Enhancing patient-centered communication and collaboration by using the electronic health record in the examination room”. In: *JAMA* 309.22 (2013), pp. 2327–2328.
- [72] Antoine Widmer et al. “Facilitating medical information search using Google Glass connected to a content-based medical image retrieval system”. In: *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE*. IEEE. 2014, pp. 4507–4510.
- [73] wikipedia.com. *Google Glass*. URL: http://en.wikipedia.org/wiki/File:A_Google_Glass_wearer.jpg (visited on 02/25/2015).
- [74] Peggy Wright, Diane Mosser-Wooley, and Bruce Wooley. “Techniques & tools for using color in computer interface design”. In: *Crossroads* 3.3 (1997), pp. 3–6.
- [75] Jie Yang et al. “Smart sight: a tourist assistant system”. In: *Wearable Computers, 1999. Digest of Papers. The Third International Symposium on*. IEEE. 1999, pp. 73–78.

Appendix A

Hardware Specifications

Google Glass Specifications

Operating system: Android 4.4.2

CPU: OMAP 4430 SoC, dual-core.

Memory: 2GB RAM.

Storage: 16 GB Flash total (12 GB of usable memory).

Display: Prism projector, 640 by 360 pixels (equivalent of a 25 in/64 cm screen from 8 ft/2.4 m away).

Sound: Bone conduction transducer.

Input: Voice command through microphone, accelerometer, gyroscope, magnetometer, ambient light sensor, proximity sensor.

Controller input: Touchpad, MyGlass phone app.

Camera: Photos – 5 MP, videos – 720p.

Connectivity: Wi-Fi 802.11b/g, Bluetooth, micro USB.

Power: 570mAh Internal lithium-ion battery.

Weight: 43g (1.51oz).

Samsung Galaxy Tab Specifications

Dimensions: 243.4 by 176.4 by 8 mm (9.58 by 6.94 by 0.31 in)

Weight: 487g (1.07 lb)

Resolution: 1280 by 800 pixels (149 ppi pixel density)

Multitouch: Yes

OS: Android OS, v4.4.2 (KitKat)

Chipset: Qualcomm Snapdragon 400

CPU: Quad-core 1.2 GHz

Internal Memory: 16 GB, 1.5 GB RAM

Primary Camera: 3.15 MP, 2048 by 1536 pixels

Secondary Camera: 1.3 MP

Loudspeaker: Yes, with stereo speakers

WLAN: Wi-Fi 802.11 a/b/g/n, dual-band, Wi-Fi Direct, hotspot

Bluetooth: v4.0, A2DP

Sensors: Accelerometer

Appendix B

Information Sheet and Consent Form

Figure B.1: Information Sheets



Department: Human Interface Technology, University of Canterbury
Telephone: 02102506334
Email: muhammad.yakubu@pg.canterbury.ac.nz
Date: December 2014

INFORMATION SHEET

RESEARCH STUDY: A Study of the Usability of Hybrid Display Systems in Clinical Ward

Round

Investigators: Prof. Mark Billinghurst, Dr. Agnieszka Szostek, Dr. Pleayo Tovanante, Dr.

Gun Lee, Muhammad Nda Yakubu (Mo)

What is the purpose of the study?

You are invited to participate in a study which will investigate how doctor-patient interaction during ward round can be improved, investigate the usability of a hybrid display system, that is a combination of Google Glass and Tablet PC for accessing information in a clinical ward round scenario. The study will also measure the doctor-patient interaction in clinical ward round. The system duplicates functionality available in commercial applications. This study has been reviewed and approved by the Human Ethics Committee Low Risk Approval process at the University of Canterbury.

Procedures

Your team will be provided with a combination Google Glass-Tablet PC and we will ask you to examine a patient (role-playing actor) and retrieve information from the devices. You will be required to attend to the patient in a professional manner and be as realistic as possible. The junior doctor will use the tablet or patient folder depending on the scenario, while the senior/more experienced doctor will use either a Google Glass for accessing patient information, or paper-based clinical note. Each experiment is expected to take no more than 30 minutes.

Possible Risks

There are no anticipated risks to your participating other than those encountered in daily life. Should you feel any discomfort (e.g. dizziness, headache) and feel that you cannot continue with the experiment or if you would like to take a break please advise the experimenter.

Benefits

The results of this experiment will help to evaluate new techniques for developing hybrid display systems and wearable technologies for accessing digital information in the hospital.

Figure B.2: Information Sheets

Compensation

You will receive a gift.

By signing this consent form you acknowledge and agree that, in the event that this research project results in the development of any marketable product, you will have no ownership interest in the product and no right to share in any profits from its sale or commercialization.

Payment For Injury or Harm

Taking part in this research study carries the risks explained under the section entitled “POSSIBLE RISKS”. If you require immediate medical care and are not a hospitalized patient, you should seek immediate medical treatment (take your informed consent form with you). Otherwise the investigator will help you get the care you need. The University of Canterbury, and/or the investigators will not pay for the care. Likewise, the University of Canterbury, and/or the investigators will not pay you for pain, worry, lost income, or non-medical care costs that might occur from taking part in this research study.

Right To Withdraw From Study

Participation in this experiment is voluntary. You are free to withdraw your consent and discontinue your participation in the experiment at any time, without prejudice to you.

Confidentiality

The data collected from your participation will be collected in an anonymous form, and will not be released to anyone except to the researchers directly involved in this project. Your data will be assigned an anonymous ID code. When reporting on the data collected from this experiment, only this subject number will be used when referring directly to your data.

Data will be collected mainly using questionnaires, video recordings and structured interviews. All data collected will be kept secure in a secure web server only accessible to the researchers, and will be destroyed after 5 years upon completion of the experiment.

The project is being carried out as part of Master of Human Interface Technology degree by Muhammad Nda Yakubu under the supervision of Professor Mark Billinghurst, who can be contacted at mark.billinghurst@canterbury.ac.nz. He will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee Low Risk Approval process, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return.

Questions

Should you have any questions about the study please contact:

Muhammad Nda Yakubu (Mo), University of Canterbury

mobile 02102506334

email muhammad.yakubu@pg.canterbury.ac.nz

Please take this sheet with you when you leave.

Figure B.3: Consent Form



Department: Human Interface Technology, University of Canterbury
 Mobile: 02102506334
 Email: muhammad.yakubu@pg.canterbury.ac.nz
 Date: December 2014

Consent Form

Title of Project: A Study of the Usability of Hybrid Display System in Clinical Ward Round

Investigators: Prof. Mark Billingham, Dr. Agnieszka Szostek, Dr. Pleayo Tovarante, Dr. Gun Lee, Muhammad Nda Yakubu (Mo)

I have been given a full explanation of this project and have had the opportunity to ask questions. I understand what is required of me if I agree to take part in the research.

I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.

I understand that any information or opinions I provide will be kept confidential to the researcher and his supervisor and that any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.

I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.

I understand that there are no anticipated risks to your participating other than those encountered in daily life.

I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.

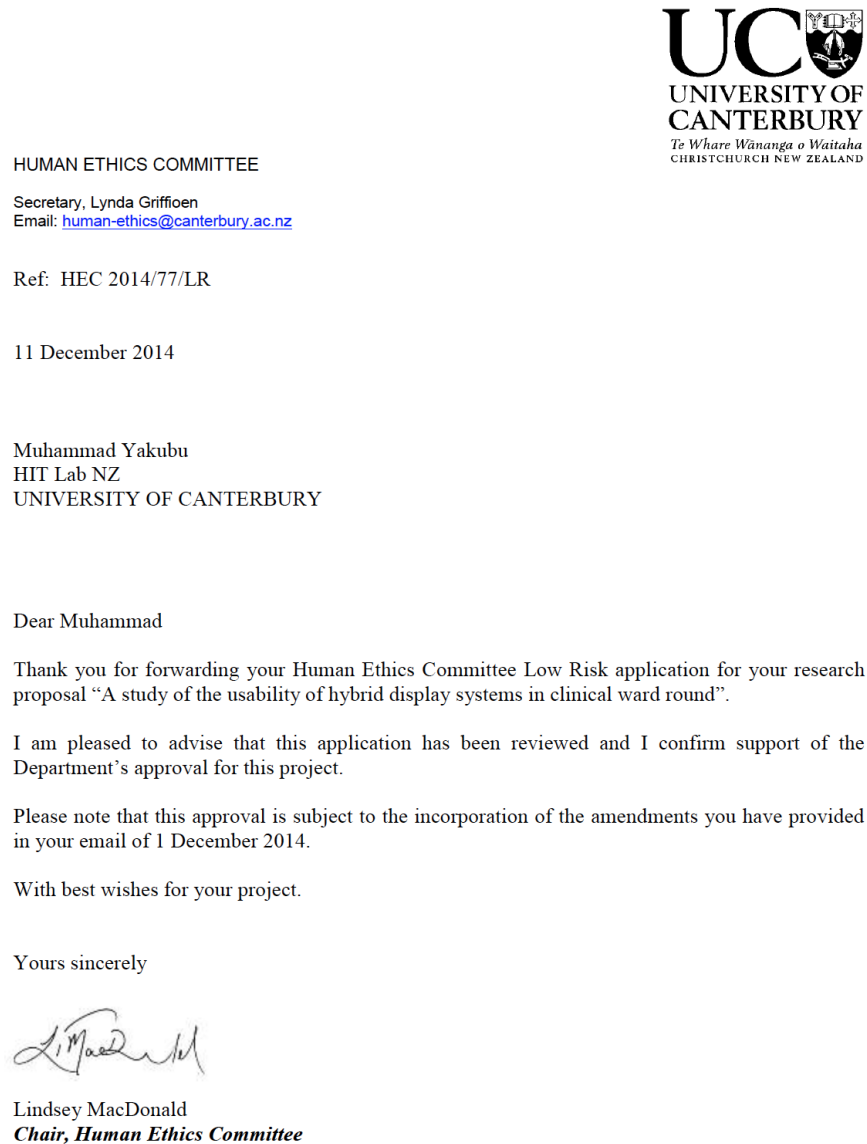
I understand that I can contact the researcher Muhammad Nda Yakubu (Mo), muhammad.yakubu@pg.canterbury.ac.nz or supervisor Prof Mark Billingham, mark.billinghurst@canterbury.ac.nz for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

By signing below, I agree to participate in this research project.

Name of Participant:

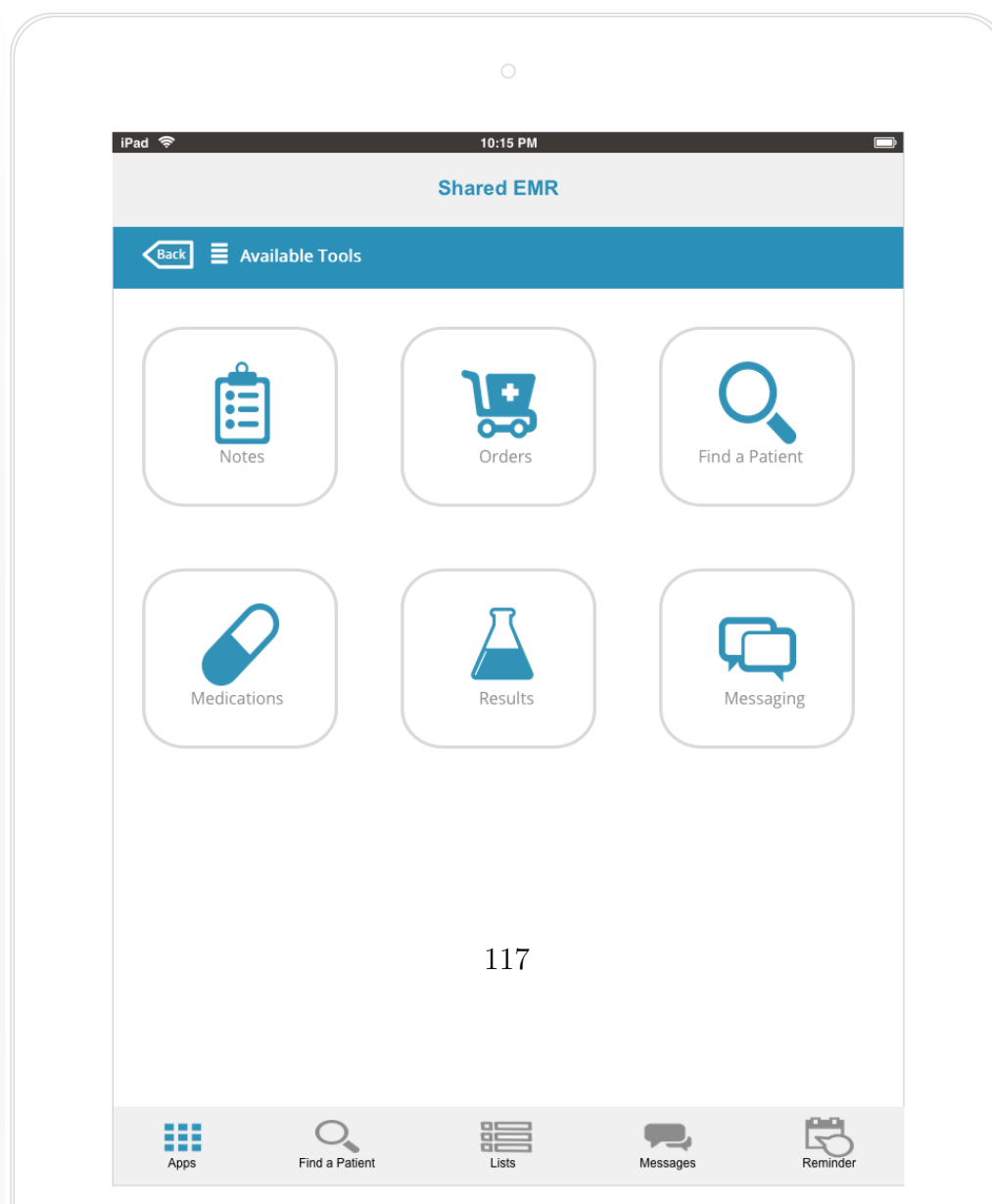
Signature of Participant:

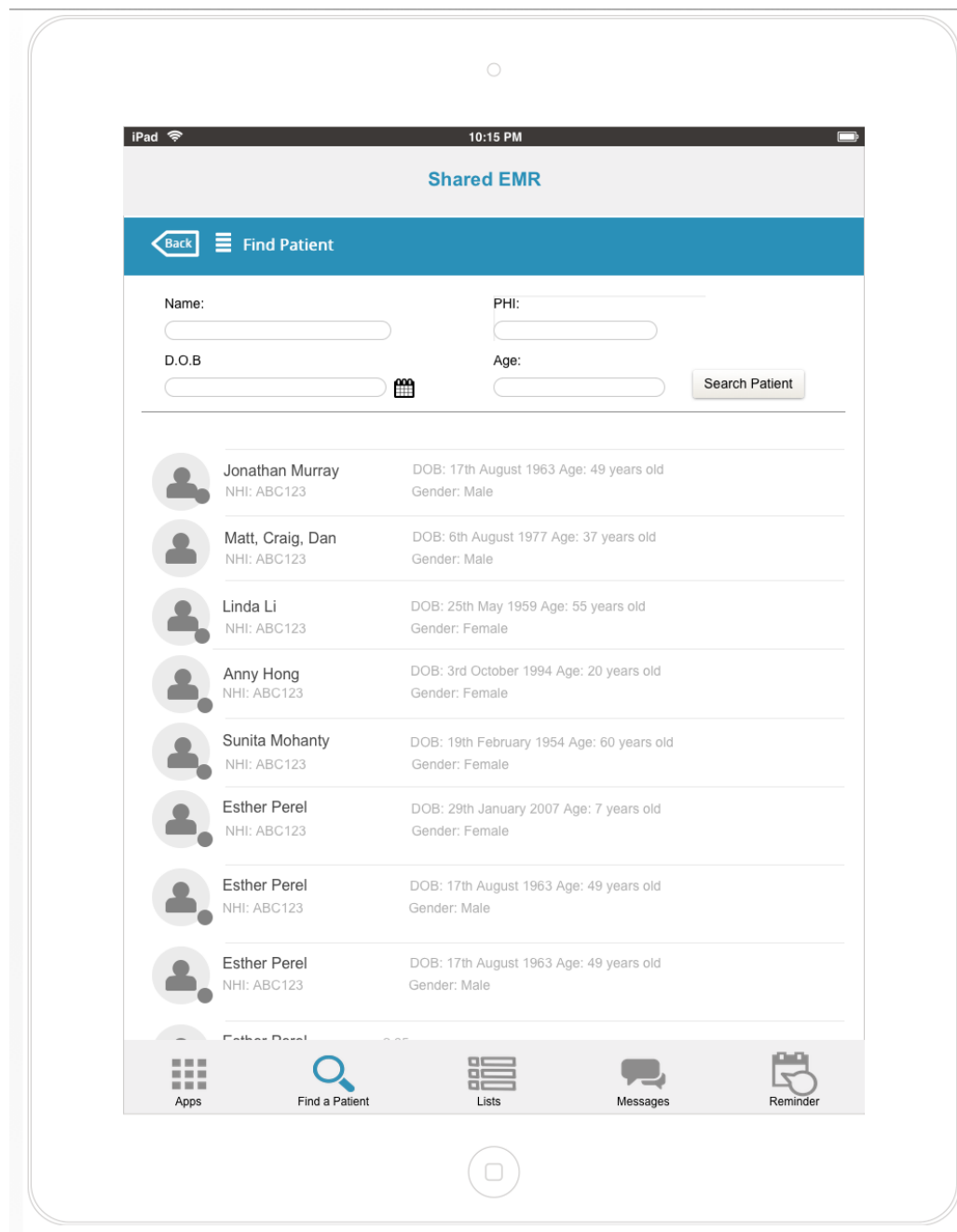
Figure B.4: Ethics Approval

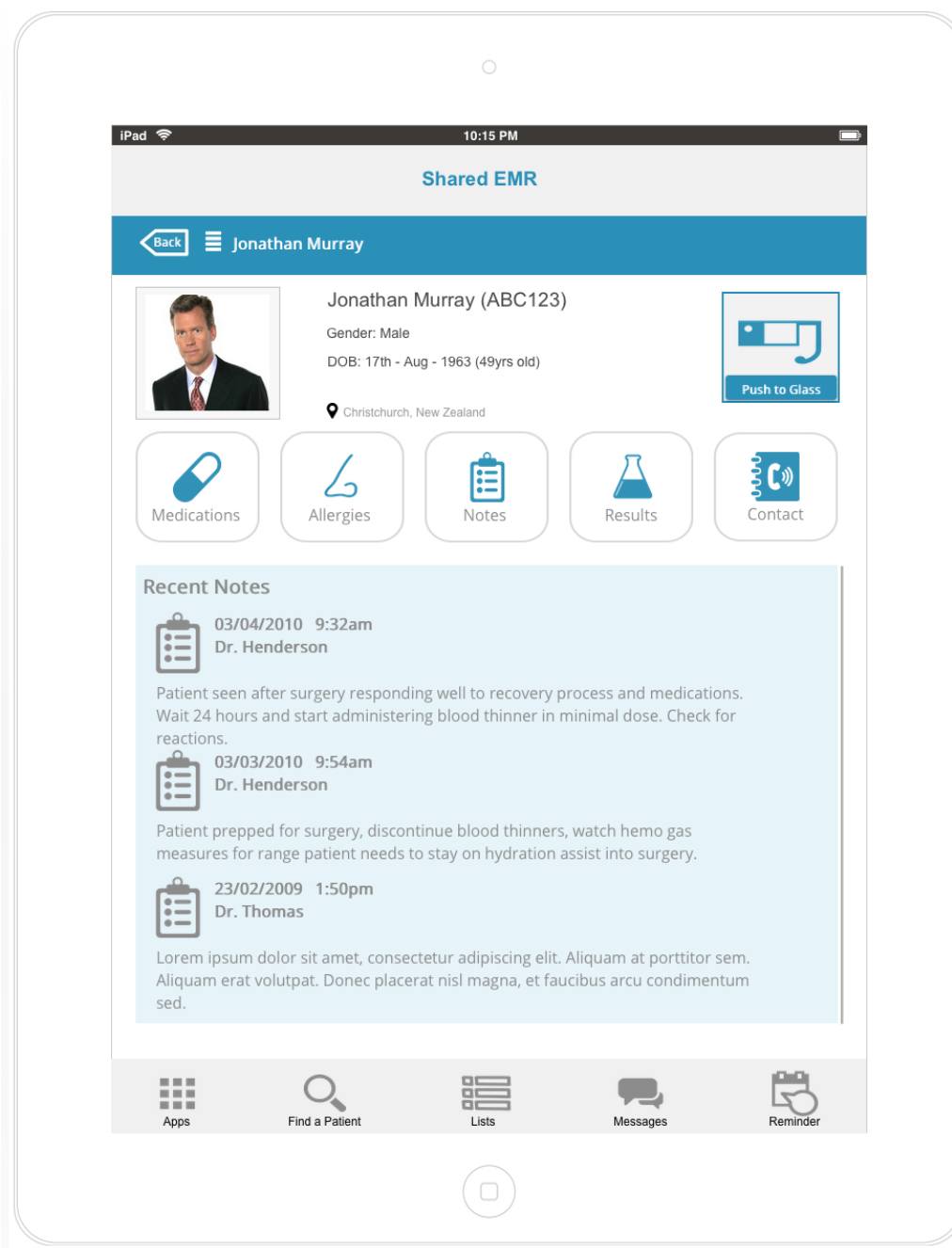


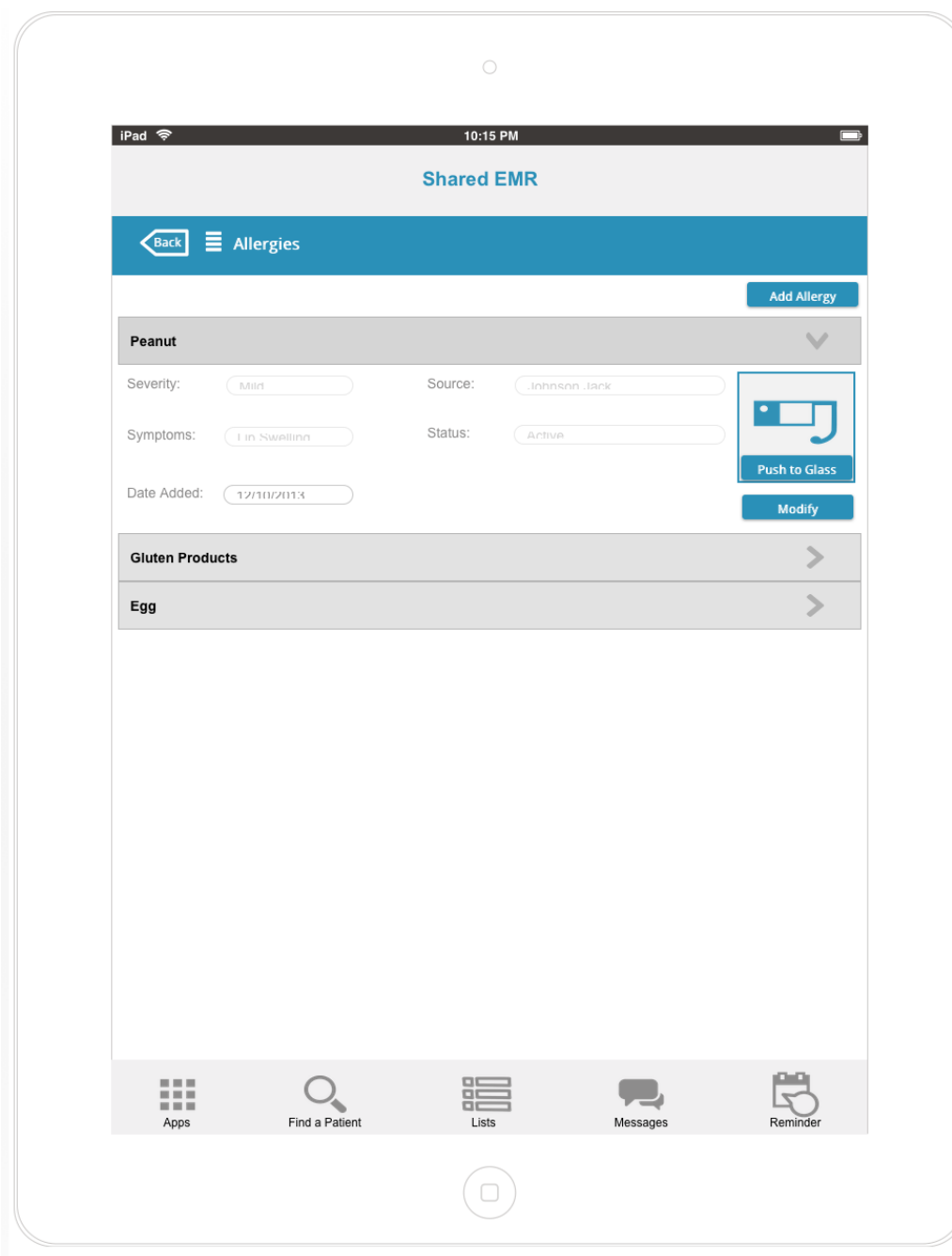
Appendix C

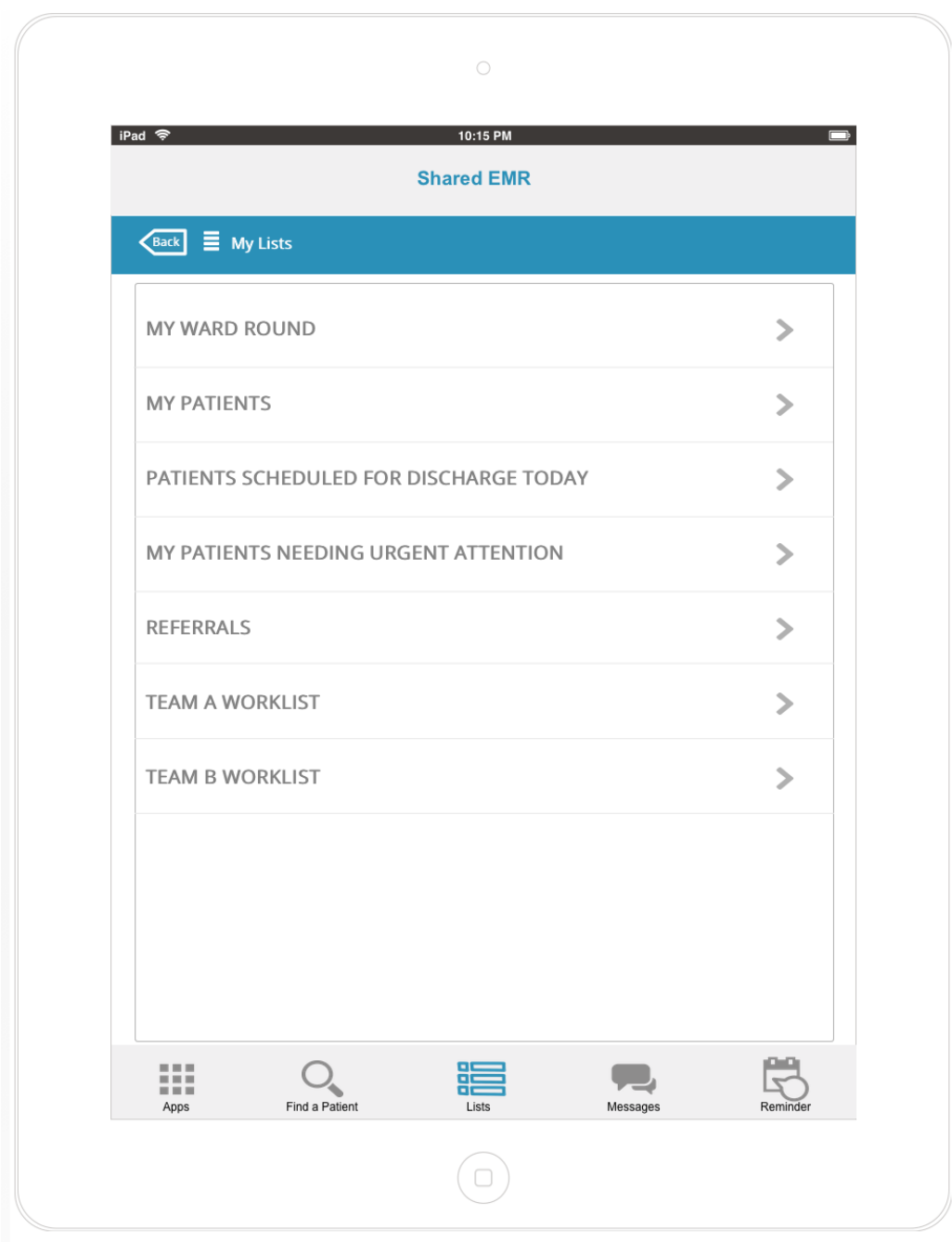
High Fidelity Prototype













A screenshot of a patient demographic view on Google Glass. It features a dark grey background with white text. On the left is a small portrait of a man. To the right of the portrait, the patient's name is displayed in a large font, followed by his medical unit, date of birth, age, and gender. At the bottom, his room and bed number are on the left, and his length of stay is on the right.

	Jonathan Murray General Ward Acute Stroke Unit DOB: 17th - August - 1963 Age: 49 yrs old Gender: Male
Room 3, Bed 1	LOS: 7 days

Figure C.1: Patient Demographic View on Google Glass



A screenshot of a patient allergy view on Google Glass. It features a dark grey background with white text. On the left is a blue icon of a hand holding a pen. To the right of the icon, the allergy name is displayed in a large font, followed by its severity, symptoms, date added, source, and status. At the bottom, the number of allergies is on the left, and the patient's name is on the right.

	Allergic to Peanut Severity: Mild Symptoms: Lip Swelling Date Added: 12/10/2013 Source: Jonhson Jack Status: Active
Allergy (1/3)	Jonathan Murray

Figure C.2: Patient Allergy View on Google Glass

Appendix D

Final Prototype



Mr. Keith Simpson

NHI: EWS433

Gender

Male

Occupation

Engineer

Ethnicity

NZ Maori


12-October-1972

2 mins ago


□

○

◀



Patient Info



← → ↺

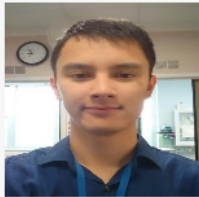
hybridehr.herokuapp.com/patient/15

☆ 🔊 ⋮

⏪

Patient Info

⏩





Keith Simpson


NHI: EWS433


Gender: Male


DOB: 12-October-1972



Push to Glass



Notes


GP Referral


Presenting Complaint


Medication


Allergies


PMH


Medications


Push all medications to Glass


⊖ NSAIDs


NSAIDs

p.r.n.



 Find Patient

 Patient Info

 Messages

Drug: NSAIDs

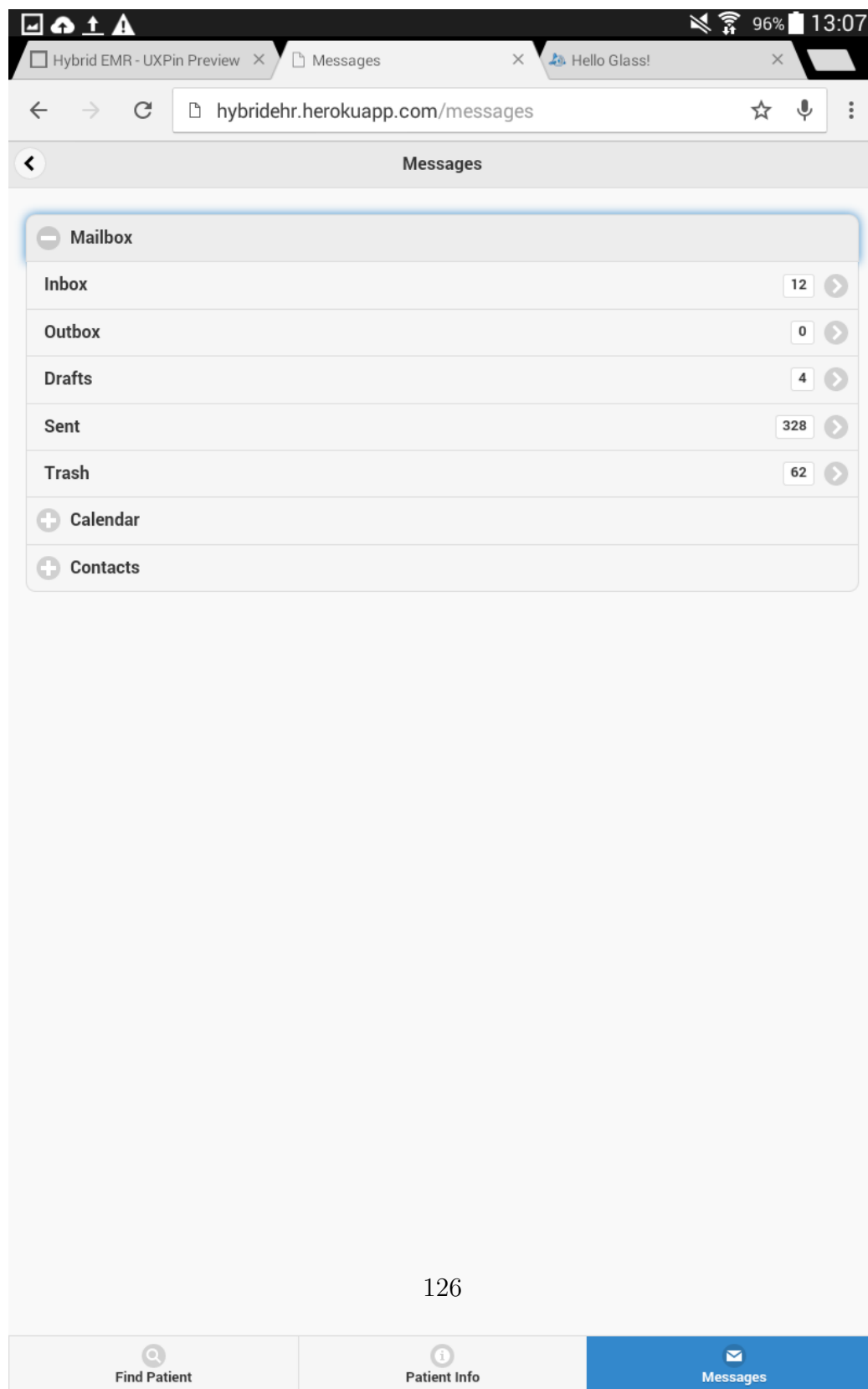
Instruction: p.r.n.

Medication

□

○

△

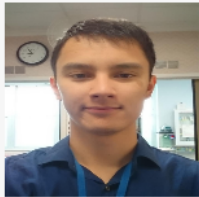


Patient Info


hybridehr.herokuapp.com/patient/15

18:23

Patient Info



Keith Simpson
NHI: EWS433
Gender: Male
DOB: 12-October-1972


Push to Glass

PMH

Family History

Social History

Observati...

Result

Plan

Result

Urine Test

Click to view result attachment:

View Result

Find Patient

Patient Info

Messages

Appendix E

Experiment Advertisement

ceo update

Invitation to take part in wearable technology research

CDHB clinicians are being invited to try Google Glass as part of research to be carried out by Orion Health Software Engineer, Mo Nda Yakubu.

Mo wants to work with CDHB clinicians to undertake research into the use of wearable technologies, including Google Glass, in patient care.

Google Glass is an optical head-mounted device that displays information in a smartphone-like hands-free format. Wearers communicate via the internet using natural language voice commands.

Mo's research will investigate how new technologies such as Google Glass can be used in healthcare. In particular, how doctor-patient interaction can be improved using Google Glass during patient ward rounds in the hospital.

Participation involves carrying out an experiment using software installed on Google Glass and filling out a questionnaire at the end of the experiment. Participation is voluntary, will take no longer than 45 minutes and is completely anonymous.

No individual will be identified and information collected will be kept strictly confidential.

Before moving to New Zealand to study software engineering, his parents wanted him to study medicine and become a medical doctor, Mo says.

"But because of my passion for software development I convinced my parents to let me study software engineering."

Mo joined Orion Health in 2011.

"This allowed me to work in the healthcare field as my parents wanted me to. As a software engineer, I get to work in a field I am passionate about and design and build software for doctors, who in return save people's lives."

Mo was part of a joint innovation week between CDHB and Orion Health. He visited Christchurch Hospital, talked to clinicians about their day-to-day interaction with software and observed how they were used for day-to-day work.



"From what I gathered, a lot of clinicians find a lot of the software complicated, time-consuming and counter-intuitive."

This realisation motivated him to pursue a Masters Degree in Human Interface Technology specialising in Interaction Design at the HITLab, University of Canterbury, he says.

The research will be conducted during the month of November at Christchurch Hospital (exact dates and time to be confirmed).

To register your interest: Please fill out the form on <http://goo.gl/gSRXRL>.

Left: Google Glass in use.



Mo Nda Yakubu

Appendix F

Patients Clinical Note Folders

Canterbury

District Health Board

Te Pori Hauora o Waitaha

Rebecca Smith

BAHCOOL

#1

CONFIDENTIAL PATIENT RECORD

NOT TO BE REMOVED FROM THE HOSPITAL
OR COPIED WITHOUT AUTHORISATION

Integrated CDHB Clinical Record

ADVERSE EVENT, ALLERGY AND WARNINGS

Penicillin -

Angioedema

Rebecca

SMITH

BARCODE LABEL

THIS IS NOT A COMPLETE PATIENT RECORD.

PLEASE VIEW THE ELECTRONIC VERSION FOR
ADDITIONAL INFORMATION.

NAME Rebecca Smith N.H.I. _____

SEX F AGE 35 WARD _____

(Fix label here or fill in)

CLINICAL NOTES

DATE / TIME	
	<u>ED Admission</u>
	35 year old lady BIBA
	<u>PC</u> SOB
	<u>HPC</u> Worsening SOB 3/7
	Fever at home T = 38.9°C 2/7
	Coughed up sputum, chills, night sweats
	Wheezing and cannot get air in
	Called ambulance
	<u>PMHx</u> • Asthma since aged 8
	• previous hospital admissions
	• Migraine
	• Granulomatous cystitis (2003)
	<u>Meds</u> • Flixotide Inhaler 125µg/puff 2puffs b.d.
	• Salbutamol Inhaler 100µg/puff 2puffs p.r.n.
	• Paracetamol 1g qid
	• Magnesium 1 tab once
	<u>Allergies</u> • Penicillin - anaphylaxis
	Latex - Contact dermatitis
	<u>Social Hx</u> - Lawyer, non-smoker
	- Married with 2 children aged 1 & 2
	- Lives at home with husband
	- Husband smokes cigarettes (outside the house)

CLINICAL NOTES

QMR0003

(CONTD. OVER PAGE)

NAME _____ N.H.I. _____

SEX _____ AGE _____ WARD _____

(Fix label here or fill in)

DATE / TIME

Family Hx: Sister has eczema/hay fever
Mother has asthma

O/E Alert, conscious
Anxious/agitated
Breathless rr
Audible wheeze rr
Speaks in broken sentences

T = 38.7°C

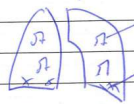
RR = 30

BP = 155/82

SpO₂ = 90% on 1L O₂

HR = 110 bpm regular

Accessory muscle use



audible expiratory wheeze throughout

crackles at bases bilaterally

H.S. - dull with no murmurs.

Abdomen - soft, non-tender
BS active

Imp Acute asthma exacerbation +/- pneumonia

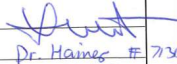
Plan IV fluid + salbutamol nebs

IV Augmentin

Bloods

Chest X-ray

Refer to General Medicine


Dr. Haines # 730

Issue Date September 2006

(Attach Patient Label or Complete Details)
SURNAME: Rebecca Smith NHI: _____
GIVEN NAME: _____ GENDER: ☐ M ☒ F
DATE OF BIRTH: _____ AGE: 35

Adult Observation Chart

Date		EWS										Height		Date	
Time		0 1 2 3										cm		Time	
Airway	Patent													Patent	Airway
	Under threat													Under threat	
Respiratory Rate (breaths/min)	35													35	
	30													30	
	25													25	
	20													20	
	15													15	
	9													9	
	5													5	
SpO ₂	90													SpO ₂	
O ₂ L/%	1L													O ₂ L/%	
O ₂ method														O ₂ method	
Heart Rate (beats/min)	150													150	
	140													140	
	130													130	
	120													120	
	110													110	
	100													100	
	90													90	
	80													80	
	70													70	
	60													60	
	50													50	
	40													40	
	30													30	
Rhythm	Reg/irreg													Rhythm	Reg/irreg
MAP	210													210	
X	200													200	
	190													190	
Blood Pressure (mm.Hg)	180													180	
	170													170	
Score EWS for Systolic BP	160													160	
	150													150	
Record as	140													140	
↑	130													130	
↓	120													120	
Lying BP = L	110													110	
Standing BP = S	100													100	
	90													90	
	80													80	
	70													70	
	60													60	
Temperature °C	39.0													39.0	
	38.0													38.0	
	37.0													37.0	
	36.0													36.0	
	35.0													35.0	
Neuro	Alert													Alert	
	Voice													Voice	
	Pain													Pain	
	App/Conf													Agitation/Confusion	
	Unresp													Unresp	
Urine EWS														Urine EWS	
TOTAL EWS	6													TOTAL EWS	
Pain Score 0-5														Pain Score 0-5	
Sedation Score 0-3														Sedation Score 0-3	
Phlebitis Score														Phlebitis Score	
Bowel Motion														Bowel Motion	
Weight	65													Weight	
Initials	RS													Initials	

ADULT OBSERVATION CHART

C28010

Fluid Prescription Chart

Name Rebecca Smith NHI

Sex F DOB 35yo Ward _____

(Affix label here or fill in)

[illegible]

ment must be ordered in accordance with RMO's Hair

DESCRIPTION CHART

Q
M
R
O
O
4
B

FLUID PRESCRIPTION CHART

Adverse Reaction

YES - attach completed sticker
QL00250

☐ No known adverse reactions

Name: Rebecca Smith NHI: _____

Sex: F Age: 35 Ward: _____

Consultant/Team: ED

DRUG TREATMENT SHEET

HEIGHT	cm
WEIGHT	Kg
LEAN BODY WEIGHT	Kg
SURFACE AREA	m ²

PATIENT HAS OTHER
DRUG TREATMENT
SHEETS ☐

CHRONIC
RENAL
IMPAIRMENT ☐

ABBREVIATIONS PERMITTED ON DRUG TREATMENT SHEETS

b.d.	twice daily	q.4.h.	every 4 hours, etc	i.v.	intravenous
t.d.s.	three times a day	a.c.	before food	p.o.	oral
q.i.d.	four times a day	p.c.	after food	p.r.	rectal
mane	in the morning	p.r.n.	as required		
nocte	at night	i.m.	intramuscular		

ONCE ONLY/PREANAESTHETIC MEDICATION/VERBAL ORDERS

Verbal orders must be written in RED and countersigned by doctor within 24 hours

Code	Date	Drug and Dose	Time to be Given	Route	Prescriber's Signature Surname Print	Time Given	Initials	Second Check
		AUGMENTIN 1.2g	stat	IV	<i>[Signature]</i> Haines	11.00	Jb	GT
		SALBUTAMOL 5mg via spacer	stat	Neb	<i>[Signature]</i> Haines	11.00	Jp	GT

USE CAPITALS FOR DRUG NAMES AND SURNAME

Treatment must be ordered in accordance with Standing Orders for R.M.O.'s

Appendix G

Patient Scripts

INSTRUCTIONS FOR SIMULATED PATIENT 1

(Female, age 35)

You are **Rebecca Smith, a 35-year-woman**, a lawyer by profession, married with 2 children.

You have been feeling acut`ely unwell with fever and breathlessness and was brought into hospital's Emergency Department last night.

You have had asthma since age 8. You have been in hospital a few times before with a serious asthma attack, usually brought on by a chest infection. Your asthma is normally well controlled and you are otherwise well.

You don't smoke. You have had a cough and a yellow mucous over the last 2-3 days and have been feeling a little more breathless than normal. You normally take a brown inhaler twice a day and a blue inhaler when you need it. Recently you have been taking your blue inhaler more often as you have been more wheezy than normal. Over the last 2 nights, you started to develop fever, chills, and night sweats. You have been unable to sleep due to cough and wheeze and you have now been brought into the hospital with sudden worsening of breathlessness, cough, wheeze and fever.

At the beginning of the scenario you are alert and anxious / agitated and very breathless and wheezy (be careful not to over-breathe for too long!). You have a chesty cough. You are sitting bolt upright and are only able to speak in broken sentences due to the breathlessness. Now and again you can ask the doctor to help you or say that you can't get a breath but don't speak too much, you are trying to conserve your energy. As you become more breathless, you start to use your neck and shoulder muscles to help you breathe – we will show you how.

Past Medical History:

- Migraine
- Had Ovarian cystectomy removed in 2003

Social circumstances:

You live with your husband and 2 kids, aged 1 and 2 years. Your husband smokes cigarette outside the house.

Allergy:

- You are allergic to penicillin - angioedema

- Latex - Contact dermatitis.

Current Medications:

- Flixotide inhaler
- Salbutamol inhaler
- Paracetamol
- Magnesium

Family History:

- Sister has eczema and hayfever.
- Mother has asthma.

After the experiment, you will be asked to rate how you felt about the interaction with the doctor(s).

If the doctor(s) ask(s) you a closed-ended question, then you should reply to that question only. If the doctor(s) ask(s) you an open-ended question, you should feel free to expand on the answer you give.

Do your best to put yourself in the actual role of the patient and respond as you might in that situation. If you feel uncomfortable, for example, you would offer less information.

INSTRUCTIONS FOR SIMULATED PATIENT 2

(Male, age 50)

You are **Alan Nicholson, a 50-year-man**, currently unemployed, but worked as a hotel porter until recently.

You have been feeling unwell, tired, lacking energy and appetite to the extent that you were staying off work and consequently lost your job (2 weeks ago). Because of the blood tests and your increased tummy size and weight gain (approximately 8-9kg in the last 2 months) your GP, Dr. Smart sent you to the Emergency Department.

You have noticed some abdominal swelling over the last 6-8 weeks and the waistbands on your trousers are tighter.

You have difficulties breathing, especially on exertion. You are not very fit (don't exercise regularly) but did not previously have difficulty breathing.

You do not have sharp or severe pain, but have some abdominal discomfort as a result of the abdominal swelling/trouser waistbands being tight/breathlessness.

Your friends and former work mates have commented on your yellow skin colour. This seems to be an issue some days, but not others. You noticed that, every now and again, your urine is darker in colour. There is no change in your bowel habits. *If asked*, you have not had black stools. You have not noticed any other skin conditions. (Student may ask about "Spider naevi" - small skin lesions and/or bruising. *If asked*, you do not bruise easily)

There is also this lack of concentration. You previously enjoyed playing cards but are finding it difficult to stay focussed. This is also the case when you read the newspaper, do crosswords etc. Your wife has noticed it too. You are sleeping or at least dozing off during the day but you are sleeping less at night. Your wife has also accused you of being more forgetful than usual. She thinks that you might have Alzheimer's disease or as your friends say, "Old-timers disease".

Your appetite is not as good as it was a few months ago. *If asked*, No nausea or vomiting. Your diet is not very good. You do not fancy large meals and you do not eat regularly. Your wife is at work during the day and you just snack on biscuits and left-overs. When you are out with your mates you have fish & chips.

Past Medical History:

- You were involved in a car accident 20 years ago when you suddenly lost control over your car after a night out. You do not want to expand on this (you make a suggestion there was alcohol involved, but don't want to talk about this any more).

- No other medical conditions that you know of.

Social circumstances:

You live alone currently in council's flat, you have recently divorced your wife Irene, your wife of 24 years. You have 3 adult children. You have held various jobs as a general labourer and most recently worked as a hotel porter in town. You smoke about a pack of cigarettes (20) a day since age 15 and have no reason to quit. You are currently unemployed.

Alcohol Intake:

According to you, you drink about as much your workmates do which is on average is 3-4 stubbies per day (no more previously). Of course on the weekends and during rugby season it can be more, about 2 or 3 jugs on a night. You also enjoy about 2-3 whiskeys per day, a bottle usually lasts a week. When you are working, your alcohol intake is usually a little bit less but that depends on the type of work. If it is hard work, you tend to drink more beer because you sweat and feel thirstier. But then, drinking is not bad is it? Your wife always nags about your drinking habit, especially when you had a few too many with your mates. You have tried to reduce a couple of times but soon went back to the old habit.

Other:

You tried IV drugs as a teenager but you did not share the needles.

You had tattoos applied to your upper arms during your OE in Amsterdam some 30 odd years ago. **Patients will need to wear long sleeves.**

Family History:

- Father had heart failure.
- Mother has Thrombosis.

Your character

- You are an easy going, cooperative person, who will respond to an empathetic doctor.
- You are feeling the strain of losing your job and dealing with an undiagnosed health problem.
- You see no connection whatsoever of your drinking habit with your current illness. In fact you start getting annoyed that everybody is just asking about your drinking. You think that all doctors have probably previously talked to your wife...
- Lately you can get more irritated and get angry even about little things.

After the experiment, you will be asked to rate how you felt about the interaction with the doctor(s).

If the doctor(s) ask(s) you a closed-ended question, then you should reply to that question only. If the doctor(s) ask(s) you an open-ended question, you should feel free to expand on the answer you give.

Do your best to put yourself in the actual role of the patient and respond as you might in that situation. If you feel uncomfortable, for example, you would offer less information.

INSTRUCTIONS FOR SIMULATED PATIENT 3

You are **Mr Keith Simpson, your age is 42 years old**. You are a previously well man, but came to the emergency department because you've been suffering from severe abdominal pain that came on suddenly 48 hours ago and comes in waves about every 20 or 30 minutes. The pain is very severe (if asked, on a scale of 1-10, you would rate the pain as being 8/10). You are a self-employed engineer and happily married father of three.

You start off by saying: "I've had really bad abdominal pain over the past couple of days. I thought it might go away on its own but the pain keeps coming every 20 or 30 minutes. There isn't anything I can do to get comfortable and having said that, nothing I do seems to make it get any worse. I've been feeling a bit sick, like I might throw up; I'm worried it might be something serious".

The following is the expected history and findings on examination:

1. History

You are a previously well person who has developed sudden severe abdominal pain for the first time 48 hours ago. The pain occurs in waves, about every 20 or 30 minutes. It makes you writhe around and there is nothing you can do to reduce the pain. Similarly, nothing seems to make it worse. The pain is felt entirely on the right side of your abdomen, quite high up and especially towards your back. It radiates down toward the lower abdomen on the right side. The pain makes you slightly nauseous, but you have not vomited.

If asked, you have not had fever nor have you been jaundiced (yellow-looking skin). Your bowel function has been normal: no pale stools etc. You have not had blood in the urine or had dark coloured urine. Your bladder function is normal, no increased urge to urinate or increased frequency of urination.

You don't remember having had a sick day in your adult life and have never been hospitalised. You are not on any medication. You have an **occasional social drink** (mostly beer, maybe 3-4 units/week) and are a **non-smoker**.

2. Examination

At present you are pain free – a lull between episodes. The doctor will find no abnormality except for some tenderness high on the right side and only when examined deeply over the right kidney. It is more tender towards your back. When examining the right kidney it will cause you to "tense up" with the discomfort.

After the experiment, you will be asked to rate how you felt about the interaction with the doctor(s).

If the doctor(s) ask(s) you a closed-ended question, then you should reply to that question only. If the doctor(s) ask(s) you an open-ended question, you should feel free to expand on the answer you give.

Do your best to put yourself in the actual role of the patient and respond as you might in that situation. If you feel uncomfortable, for example, you would offer less information.